ANTIQUES
THEIR RESTORATION AND PRESERVATION

Made and Printed in Great Britain by
Butler & Tanner Ltd., *Frome and London*

PREFACE

The literature dealing with methods of treating ntique objects, with a view to their restoration nd preservation, is very scanty, and all that exists n the subject are the few books and pamphlets nentioned in the Bibliography at the end of the resent volume, together with occasional scattered rticles in scientific journals and brief notes in rchæological reports. The author, therefore, who as made a special study of the subject, and who or two seasons has been helping with the cleaning nd preservation of the objects from the tomb of 'ut-ankh-Amen, has ventured to write a small book the hope that it may be useful to archæologists, useum curators, collectors and others The book admittedly elementary, and the author has endea- oured to be as simple and non-technical as possible [e has also tried to be definite, and where there are number of different methods to indicate the best. t must be remembered, however, that no one remedy n be of universal application and that each case ould be treated as a separate and special study, nd, in order that this may be done, the underlying

principles are fully explained. The methods recommended are neither difficult nor expensive.

A certain amount of repetition has been unavoidable, as many of the subjects overlap one another.

Some of the instructions and cautions given may possibly appear trivial and unnecessary, but experience proves that many of them are frequently neglected.

In order to save needless repetition, the nature and strength of the materials and solutions recommended for use are described all together at the end of the book.

The common chemical names in ordinary use, whenever they are not wrong, have been employed in preference to others that, although more technically correct, are less well known.

The author wishes to express his thanks and indebtedness to many friends who have generously helped him out of the abundance of their knowledge and experience. The usual references are given in those instances in which methods previously described are referred to.

A. L.

CONTENTS

CHAPTER I

RESTORATION

CHAPTER II

PRESERVATION

CHAPTER III

APPLICATION OF METHODS TO SPECIFIC MATERIALS

CHAPTER IV

SIMPLE PHYSICAL AND CHEMICAL TESTS

CHAPTER I

RESTORATION

1 The work of restoring and preserving antique objects naturally divides itself into two parts: first, the methods, and second, their application

The methods are scientific and largely chemical. The underlying principles are, firstly, to ascertain of what material the object to be dealt with is composed, and secondly, to determine the nature of any change or deterioration that has taken place, but, in order to apply this information, there must be, in addition, a knowledge of the properties of materials. On these data is based the appropriate treatment necessary to restore the object as far as possible to its original condition and to prevent the occurrence of any decay, or if decay is already present, to arrest its further progress and to prevent its recurrence

It may seem a very simple matter to ascertain of what material an object is

composed and, in this connection, the knowledge of other and similar objects, gained as the result of experience, is very helpful, but it is not always so simple as it appears and, in spite of experience, archæology is full of mistakes that have been made in the past. If the nature of materials is not simple, the nature of the changes and decay that have taken place is still less simple. With care, however, and by means of a few elementary physical and chemical tests gross errors on both points may be avoided, and methods of testing will therefore be given. But, as already stated, something more than this is required if serious mistakes in treatment are to be avoided, thus, for instance, it might be ascertained that a particular vase was made of alabaster (calcite) and that a crystalline efflorescence on the surface was common salt, but before this information could be usefully applied to the cleaning of the object, it must also be known that alabaster is acted upon by acid, but not by water, and that salt is soluble in water, but not in acid. This knowledge would result in the choice of water and the avoidance of acid for cleaning purposes

Although the principles on which the restoration and preservation of antiquities

are based demand a considerable amount of scientific and chemical knowledge, the application of these principles is largely a matter of skilled manipulation founded upon long training and improved by constant practice. At one time all work of the nature of that under consideration was undertaken without scientific advice, but now the tendency is often in the other direction, and the chemist is expected, not only to evolve methods, but also to carry them out. The most satisfactory arrangement, however, is to have a trained staff of skilled workmen with a consulting chemist, who has specialized in the subject, attached, and every large museum should possess such a staff For small museums, however, and for work outside museums this is not possible, and the archæologist in the field, the curator of a small museum and the collector must themselves undertake a large part of any restoration work required, and it is for these especially that the present book has been written

With respect to field work it should be recognized that this must necessarily be only preliminary and in certain cases even crude, owing to the conditions under which it is carried out, namely, absence of suitable

accommodation and proper appliances and lack of time. This being the case, field work should be limited to what is sufficient to enable the objects to be photographed, described, and, more particularly, packed and transported in safety. Detailed and final restoration work can only be satisfactorily carried out in a fully equipped workshop and by trained and experienced men, acting under the direction of the expert Much, however, can now be done in the field that formerly was thought to be impossible, and therefore was not attempted, and there are few objects, no matter of what kind, or how poor their condition, that cannot be preserved, and no object should be condemned as hopeless until it has been carefully studied and preliminary experiments made, since much that may appear at first sight to be beyond salvation can generally be consolidated and improved to at least some extent.

Methods of restoring and preserving antique objects have been practised for so long that it might seem impossible for any that are not at least fairly satisfactory to have persisted, but they do persist, and some which are not only useless, but harmful, are still employed and recommended. This is because such methods give results that appear

successful for the time being, and observations are not made, or not recorded, to show the condition of the objects after the lapse of some years.

Before proceeding to details three further points may be mentioned: firstly, the necessity for full publicity in respect to methods, secondly, the responsibility of the work, and thirdly, the pleasure of the work. In scientific work there should be no secrets, and details of processes found satisfactory should be communicated freely This unfortunately is not always done The work is delicate, and the responsibility great, and a little haste, carelessness or lack of knowledge may irreparably damage an object of beauty and value that cannot be replaced

The pleasure of the work needs to be known to be fully appreciated, but it is a real joy to see an object that has entered the workshop dirty, corroded and ugly gradually improving and finally becoming clean, healthy and beautiful.

Restoration

The first step in restoration is cleaning, and this therefore will now be considered

Manifestly the first thing to be done is to remove superficial dust and dirt. This may

usually be effected by the use of a small pair of bellows or a camel-hair or similar small soft brush. A duster should never be employed, partly because what is happening underneath cannot be seen and followed, and partly because a duster is at best a clumsy instrument and may cause damage by catching in corners or in delicate portions of a carving or in loose pieces of inlay, gilt, or paint.

After blowing or brushing off the loose dust, any more adherent dirt may generally be removed by means of water, petroleum spirit, or alcohol. The simplest reagent, namely water, should be tried first, unless it is manifestly unsuitable.

The nature of the object determines whether water should be employed sparingly or plentifully In the former case it should be applied by means of a small piece of sponge or a small camel-hair or other similar soft brush, and for small pieces of inlay and for corners by means of a tuft of cotton-wool on the end of a small piece of wood, such as a match with the head removed, or a wooden toothpick Each time the sponge, brush or cotton-wool is removed from the object it should be rinsed in clean water before being used again, the water

being frequently renewed. When water is applied in quantity the object should be immersed and well soaked. In all cases warm water is better than cold

When washing, it should be remembered that to wash a large number of times with a small quantity of water each time gives better and quicker results than to wash a few times with a large quantity of water. This is a well-known fact, which may be demonstrated chemically and proved mathematically The rule therefore for all washing is to wash frequently with a little water, though always a sufficiency, rather than to wash a few times with a large amount of water.

Before using water it must be certain that it will not have any injurious effects. This will be known as a rule from the nature of the material or from previous experience, or may be ascertained by means of an experiment on one corner of the object or on a less important object of similar kind The effects of water on various materials will be described later when dealing with the materials separately, but a few general rules will now be given, to all of which, of course, there may be exceptions These rules are as follows:

1. Articles of faience, glass and pottery, and in some instances stone, may all be washed safely, and generally need prolonged soaking in repeated changes of water Faience, pottery and stone, however, all of which are very porous and are liable to contain salt, should never be wetted unless they can be thoroughly soaked, otherwise when the object dries again the salt will be brought to the surface, where it will crystallize and cause damage

2 Articles of wood should not be wetted unless the wood is hard and in good condition, in which case they may be cleaned with a damp sponge.

3 A painted surface should never be wetted unless it is varnished or has been protected by special treatment A painted and varnished object will generally bear sponging.

4 Ivory, if in good condition, may be cleaned with a damp sponge or damp brush, or even soaked in water, but as a rule soaking should be avoided, as old ivory is very liable to split when wet Ivory in poor condition should not be wetted

5. Metals may generally be washed, but should always be thoroughly dried after-

wards In the case of silver, copper and bronze that are corroded, washing is sometimes a useful preliminary to further treatment and is always necessary after treatment.

6. Gesso and plaster, unless gilt or varnished, should never be wetted.

7. Textile fabrics should not be wetted unless they are in good condition, in which case they may be soaked, if it is necessary to clean them or to remove salt.

8. Papyrus and paper will both stand a limited amount of soaking, but special precautions are necessary in handling them while wet

9 Parchment and vellum should never be wetted

If water cannot be used, or if it has been used without success, petroleum spirit should be tried. This is applied with a camel-hair or similar soft brush, and will be found useful for painted unvarnished surfaces, when the paint is not an oil-paint (for which it is unsuitable), and generally also for varnished surfaces. Petroleum spirit is useless unless an object is quite dry In some cases, for example, on painted unvarnished surfaces, petroleum spirit may sometimes be replaced with advantage by alcohol, but alcohol

should never be used on varnish, as resins, which are the basis of most varnishes, are soluble in alcohol. Alcohol, however, may be employed with safety on both unvarnished oil-paint and on waxed surfaces. The brush used, either with petroleum spirit or with alcohol, should be well rinsed in the liquid each time after having been applied to the object, and the liquid should frequently be renewed.

When water, petroleum spirit and alcohol all prove ineffectual, special treatment is necessary, the nature of which can only be known from the kind of material and the cause of any disfigurement, and no general rules are possible. A few hints, however, may be given. These are as follows:

1. Acids and alkalies should never be employed indiscriminately for the removal of deposits, incrustations and discolorations that resist the ordinary solvents and never without a certain knowledge that they will not injuriously affect the object treated, and when employed it should only be in the form of dilute solutions, every trace of which must afterwards be removed by thorough washing. The use of these reagents will be described when dealing with the various materials.

2. Attempts should not be made to scrape or chip off hard deposits or incrustations with a penknife or other instrument, though this is often done. Thus chloride of silver is sometimes chipped off silver objects and carbonate and sulphate of lime from ivory, pottery or stone. Chipping, however, except in the cases of copper, bronze and iron, is never satisfactory, and the object will almost certainly be disfigured by scratches or even more serious damage may result. The methods of treating various incrustations will be described when dealing with the materials on which they occur.

3. Deposits and stains of an organic nature (grease, oil, resin, tar) require organic solvents to remove them, and if petroleum spirit or alcohol are not effectual such solvents as acetone, benzol or pyridine should be tried.

Two very important cautions in connection with the cleaning of antique objects that must be observed if success is to be obtained are, firstly, that all cleaning processes take time, and often a considerable time, and to hurry them means impairing their efficiency, and secondly, that it is necessary to learn when "to let well alone," and not to try and push the cleaning process too far, otherwise damage will be done.

The next step in restoration after cleaning is repairing, and this therefore will now be considered.

pairing By repairing or mending is meant the refixing of loose or broken pieces, and not the addition of new material, which will be considered later. Success in repairing is a matter of manipulative skill, training, experience, patience and care Special training in repair work and the highest degree of manipulative skill will not fall to the lot of every one who is called upon to handle antique objects, but experience, patience and care may be acquired by all

Repairs to antique objects are of such a varied nature that no detailed description is possible, and all that can be done is to give a few general principles, which are as follows:

1. Always well clean an object before repairing it.

2 Completely remove old cementing material before adding fresh. This should never be scraped off when dry, but must be softened first Glue may be softened by means of warm water, beeswax with chloroform, resin with alcohol, and paraffin wax with petroleum spirit or by heat. The solvent used should be applied with a small

brush and the softened cement wiped off with a rag or removed by means of a piece of wood or bone, such as a small paper-knife.

3. Only the best quality cementing material should be employed.

4. Patent or secret preparations of cementing material should not be used unless their general nature is known and unless their value has been well proved

5. The manner in which the various pieces of a broken object fit together should be ascertained by careful inspection and arrangement, but, as a rule, and especially if the material is friable or easily broken, the pieces should not be put actually touching one another before applying the cement, or the edges may break further.

Adhesives being essential to repairing may now be considered They are of many different kinds, but the only ones that need be mentioned in this connection are glue, casein adhesive, celluloid cement, and plaster of Paris These will now be described.

Glue —Glue is an impure gelatin, generally extracted from animal bones, skins, cartilage or tendons, but also from fish. It is one of the oldest, best known, and most reliable of all adhesives, especially for wood. It

was largely used by the ancient Egyptians, and in many instances glue on objects more than 3,000 years old is still in good condition.

Only the best quality glue and of as light a colour and as free from smell as possible should be employed. Glue, like every other soluble material, dissolves more quickly the finer the state of division, and therefore should be broken into small pieces before use This is best done by wrapping it in several folds of cloth and breaking it with a hammer. The broken pieces should then be placed in the glue-pot and just covered with water and allowed to soak for several hours but not longer, or the surface will become covered with mould. The pot should then be placed in water which is boiled until the glue is thoroughly hot and liquid. An ordinary pottery (not glass) jam-jar makes an excellent glue-pot, but should be provided with a cover in order to diminish evaporation and so prevent the glue from thickening.

For use glue should be fairly thin, about the consistency of golden syrup, but not too thin or watery, and it should be used hot. Thick or tepid glue should never be employed.

Glue is best applied by means of a brush or stick. Two forms of both will be found useful, one flat and the other round and

pointed, these should be in several sizes. The brush or stick should never be left in the glue after use, but should be removed and well washed in hot water To mend a broken object the glue is evenly distributed as a thin film on both surfaces which, if possible, should be warmed first, and these are then pressed tightly together and clamped or tied with string until the glue has set, which will take at least several hours. The greater part of any glue that oozes out is wiped off at once with a rag, but no attempt should be made to clean the surface thoroughly until the joint has set, when any glue remaining may be removed with hot water and a soft rag.

To prevent the clamps from marking the object, the surface should be protected by thin pieces of board or cardboard When string is used, pads of folded paper should be placed under the string at the edges A wooden peg inserted in the string and twisted in the manner of a tourniquet will be found useful for tightening For some purposes clothes-pegs of the kind provided with a spring, or trouser clips as used by cyclists, make useful clamps

Casein Adhesive—Casein is the protein from milk, and for the preparation of an

adhesive this protein is precipitated by acids, washed, dried, ground and mixed with small proportions of other materials, such as carbonate of soda, fluoride of sodium and slaked lime.

Casein adhesive is frequently called "cold water glue," and is sold in the form of a fine powder, which only requires mixing with cold water to be ready for use. It is about equal to the best glue in adhesive properties.

Celluloid cement consists of celluloid dissolved in an appropriate solvent. A satisfactory cement may be prepared by dissolving celluloid in amyl acetate or in acetone or in a mixture of the two. The celluloid is rasped or cut into small fragments and put into a bottle, which is then nearly filled with the solvent chosen and repeatedly shaken and finally left overnight Sufficient celluloid should be used to make a syrupy solution, which is ensured if some remains undissolved at the bottom of the bottle For use a little of the solution is poured into a small dish or saucer, and is left exposed, preferably in a warm place, until sufficient of the solvent has evaporated to produce in the remainder the right consistency for use. A cement of this nature

is now on the market put up in tubes ready for use.

Celluloid cement is waterproof, and is admirably adapted for repairing faience, glass, inlay, pottery and small stone objects, but may also be used for wood and most other materials, including even metals. It is best applied with a small camel-hair brush or a small piece of pointed wood and, as it does not set very quickly, sufficient time must be allowed for complete setting before the object is disturbed.

When using the cement on a porous object, such as faience or pottery, it should be allowed to soak well in before making the joint, or preferably, before applying the cement, the broken surfaces should be coated repeatedly with the celluloid solution as it exists before evaporation For slightly porous or non-porous material like glass or metal, the two surfaces should be coated with the cement and fitted together, and any surplus cement, which oozes out, wiped off The pieces are then pulled apart, allowed to dry, and a second coat of the cement applied and the join made again. When dry, excess cement is removed with a soft rag or soft brush dipped in amyl acetate or in acetone.

As it is rarely possible to clamp articles of faience, glass and pottery while the cement sets in the manner adopted for wood, other methods of keeping the broken surfaces together must be employed. Occasionally string or thread can be used, but as a rule the best way is to keep the joint in such a position until set that the weight of the material itself presses the edges together This may be done by standing the object in sand, plasticine or adhesive wax. When sand is used this should be clean, fine quartz sand, free from stones and dust, and should be sifted and washed before use.

Plaster of Paris.—This is employed for repairing large pottery and stone objects. Only the best quality plaster should be used

To mix plaster, take as much water in a basin as will give the required quantity of plaster, and into this scatter or shake rapidly and uniformly dry plaster in fine powder until all the water appears to be absorbed and no free water remains on the surface Stir or beat the mixture with a spoon until smooth. Use quickly

It adds to the life and durability of plaster of Paris to treat it repeatedly when dry with a dilute solution of celluloid or of cellulose acetate. This gives a slightly polished

appearance to the surface, which is not unpleasing, and after treatment the plaster may even be cleaned with a damp sponge without damage.

Plaster of Paris may also be given a good surface by impregnating it when thoroughly dry with very hot paraffin wax or stearine, any excess of which is removed by the heated blade of a penknife. The surface is then polished with French chalk and a pad of cotton-wool Stearine imparts to plaster the colour of old ivory.

Plaster of Paris is slightly soluble in water, and therefore should not be used to repair objects required to be washed or to hold water.

Sometimes an article, as, for instance, a piece of ivory, a textile fabric, gilt or painted gesso or other object is intact inasmuch as there are no parts missing, but is in such a fragile and delicate condition that it cannot be handled without falling to pieces In such a case the object manifestly must be strengthened if it is to continue to exist

The only way to treat such objects is to impregnate them with some substance that will consolidate them, and this must be applied in a liquid form. One of the most valuable of such substances is melted paraffin

wax, another is a solution of celluloid, and a third a solution of cellulose acetate.

Paraffin wax is used in the molten condition and, as a rule, very hot, and the object treated should be thoroughly dry and, if possible, previously warmed, in order that the wax may soak well in and not congeal on the surface, and the operation should be carried out in a warm place.

In order to ensure the wax being thoroughly hot, a comparatively large amount should be melted at one time, and the vessel must be one with a spout, from which the wax can be poured. A flat-bottomed copper kettle having a long spout, taking off from near the bottom, will be found satisfactory Solder should not be used for any of the joints

A fine spray of any sort is a mistake, as the wax cools very quickly and, instead of penetrating the object, congeals on the surface.

For small objects, immersing them momentarily in the melted wax and allowing them to drain is as a rule satisfactory, but the object should be warm before immersion, in order to avoid too sudden a change of temperature and must be free from blisters or other air spaces, otherwise the imprisoned

air in expanding and escaping will cause damage. Another very satisfactory way of treating small objects is to apply the wax by means of a glass pipette, one about 10 c c. capacity being a useful size The pipette should be placed quite close to the surface of the object, and the wax, which must be very hot, should be allowed to run out as quickly as possible. The use of a pipette, although a little difficult at first, is soon learned, and with care there is no danger of drawing hot wax into the mouth

If the temperature of the object and of the wax are satisfactory, the wax sinks well in without leaving any excess visible on the surface. If, however, excess wax is left, in hollows and corners, for instance, or as drops at the edges, as much of this as possible should be removed while still soft by means of a small ivory or bone paper-knife The last trace may be made either to sink in or to run off by carefully warming the object, or by slowly moving over it, almost but not quite touching the surface, a red-hot spatula or similar instrument, or by means of petroleum spirit.

Paraffin wax is colourless, damp-proof and practically unchangeable. It may be used for beadwork, bone, gesso, horn, ivory

and wood, the last-named, however, being considerably darkened in colour. It should not be forgotten that ordinary paraffin wax is not of definite composition, but is a mixture of various, though related, substances possessing different melting-points, which may range from about 32° C (89 6° F.) to about 80° C (176° F.) and, in consequence, it has not a sharp melting-point, but begins to soften at a temperature much below that at which it melts Wax with a high melting-point, therefore, should be used, otherwise it will soften during the summer or in a hot climate

Celluloid is employed in dilute solution in amyl acetate or in acetone, or in a mixture of the two, and cellulose acetate in dilute solution in acetone These solutions are either sprayed on the object or applied with a small camel-hair brush. They are used for bone, ivory, painted surfaces and textile fabrics. A useful form of spray is an atomizer or spraying apparatus as used for the throat.

enewing This is the addition of new material to replace parts of an object that are missing

There is a great difference of opinion as to what extent renewals are permissible There is no doubt, however, that, if done

at all, they should be done well and unostentatiously, and should be in complete harmony with the original and, whenever possible, of similar material and also that a detailed descriptive and photographic record of the exact condition of the object, before it was treated, should be made, and none of the old material that can be preserved should be destroyed.

Renewals are sometimes absolutely necessary, as an object may become so unstable and insecure that new strengthening material must be added if absolute ruin is to be prevented. Sometimes, however, when only a few fragments of an object remain, a model, which is frankly new, is preferable to a restoration of which very little is original and which may be misleading. The danger of adding new material is that at some time the object may be accepted or described as being entirely original and so may deceive No general rules can be laid down, but each case should be considered on its own merits.

CHAPTER II

PRESERVATION

The cleaning, repairing and strengthening of antique objects all help towards their preservation, but this treatment, useful and necessary as it is, is not sufficient, and merely to treat an object and then to put it in a museum and expect it to remain unchanged is unreasonable, and in many cases the object would last longer if left buried in the tomb. The principal dangers to museums and other collections that require to be guarded against are light, moisture and other atmospheric influences, dust, insects, bacteria and fungi. These will now be separately considered.

Light The destructive effect of direct sunlight on colours is so well known that it is often customary in ordinary households to draw down the blinds of a room exposed to the sun in order to prevent the fading of curtains, carpets and wall-paper. Not only, however, does sunlight cause certain colours to fade,

but it also causes articles, such as textile fabrics, paper, papyrus and wood, to become discoloured and tender.

Diffused daylight is also injurious, though to a less extent than direct sunlight, and even artificial light is not without effect, darkness in most cases being the only complete protection. Since, however, museum exhibits cannot be kept in darkness, the practical remedies are to avoid direct sunlight and to minimize the effects of diffused daylight by the use of shutters or black blinds to the windows when the museum is not open to the public, and of yellow blinds when the museum is open, if the sun is on the windows, or the light very bright, or of yellow covers or curtains to special show-cases containing objects that are particularly susceptible to light, except when these are actually being used Instead of blinds yellow glass might be employed, but the extra expense is not necessary if the precautions mentioned are taken. Blue- or violet-coloured material for either glass or blinds should be avoided, since the blue and violet rays of light are chemically the most active

Many of the influences destructive of antique objects cannot operate in the absence of moisture. Thus moisture is

essential to the life of bacteria and fungi to the action of salt, to many chemical changes, and probably to the fading caused by light Moisture is also injurious on account of its solvent action on various materials, more particularly when it contains, as it practically always does, carbon dioxide derived from the air, and still more if it contains, as may happen, sulphur acids from the burning of coal or coal gas. The exclusion of moisture-laden air therefore is essential. This can be done by proper attention to heating and ventilation and by the use of museum cases in which the air having access is filtered through a drying agent such as calcium chloride, or by the use of calcium chloride inside the cases. If a drying agent is employed it is necessary that it should be kept in suitable receptacles, and that it should be renewed frequently, otherwise more damage may be caused than by omitting it. For some objects, such as mummies, the atmosphere of the case should be as dry as possible, but for other objects an absolutely dry atmosphere, which however would be difficult to obtain, is not desirable, thus wood, when quite dry, contracts and cracks, and any plaster or paint on the surface breaks off.

Among injurious atmospheric influences may be mentioned too high a temperature and too great a range of temperature, and as equable a temperature as possible should be obtained.

,t Dust is objectionable, not so much on account of any direct damage it causes, although this may happen, but more especially because its presence necessitates constant handling of the objects in order to clean them The remedy against dust is to use special dust-proof cases, of which several kinds are obtainable.

ts Organic materials of almost all kinds are liable to be attacked and even utterly destroyed by insects These comprise clothes beetles, clothes moths, cockroaches, furniture beetles, silver fish and white ants, and they consume feathers, fur, hair, horn, ivory, leather, mummies, skins, wood, woollen goods, and many other materials

There are two ways of combating insect pests, firstly, to prevent their access to the materials liable to be attacked, and secondly, to kill them should the articles, in spite of all precautions, be invaded.

The best preventive measures are well-fitting show-cases, frequent inspection, and periodical cleaning, and, for such articles as

feathers, fur, hair, skins and woollen goods, the keeping of naphthalene (which is more effective than camphor) in the cases

The best cure for materials that are already attacked is fumigation with carbon disulphide. This is a liquid which, on exposure to the air, evaporates, forming a gas which is a very effective insecticide Hydrocyanic acid gas (prussic acid gas) and sulphur might also be employed, but the former is so very poisonous that its use, except by those accustomed to it, is not recommended, and fumigation by sulphur is somewhat difficult to carry out.

The simplest and most satisfactory method of using carbon disulphide is to leave the liquid, contained in suitable receptacles, exposed for about a week in the show-case in which are the articles to be treated, or to remove the articles to a special airtight case in which the fumigation is carried out Liquid carbon disulphide is very inflammable and very volatile, and the vapour also is very inflammable, and when mixed with air in certain small proportions is also explosive, it must therefore be used with necessary precautions, and fires, naked lights and smoking in the vicinity must be avoided Carbon disulphide has a very objectionable

smell, but this soon disappears from the objects treated.

If for any reason carbon disulphide cannot be employed, carbon tetrachloride, another volatile liquid but the vapour of which is not inflammable, may be used instead. This, however, is less efficient than carbon disulphide

Other preventives and remedies against certain kinds of insects are to spray the material with (*a*) petroleum spirit, (*b*) a solution of mercuric chloride (corrosive sublimate) in alcohol, which is very poisonous, or (*c*) a solution of naphthalene in carbon tetrachloride Arsenic compounds and copper compounds, which are excellent insecticides, cannot, as a rule, be used for antique objects, as they can only be employed in solution in water and water generally is to be avoided. This subject will be dealt with further when the separate materials are being considered.

ı
ıgi

Among the agents of destruction that gain access to antique objects and damage or destroy them, are bacteria and certain vegetable growths such as lichens and fungi (moulds). Thus, for example, bacteria attack mummies, lichens disfigure stone and old window glass, also aiding disintegration, and

fungi damage paper, plaster, textile fabrics and wood. These agents all need moisture and warmth for their development, and although warmth cannot be avoided, objects can with care be kept dry. The treatment of objects attacked will be described when the objects themselves are being considered

andling When dealing with antique objects it should not be forgotten that the human hands, even when clean, are always more or less moist and greasy, and that perspiration contains acid bodies and salt. In a hot country the effects of acid perspiration are very noticeable, and in the summer in Egypt, for example, blue litmus paper held in the fingers is reddened Metal and other objects susceptible to the action of moisture, acids and grease should therefore be handled as little as possible, and the hands should be covered with white cotton gloves or with a cloth

rvative ɔatings Although an object may have been cleaned and restored, it is, as already mentioned, constantly subject to agencies, such as atmospheric influences and contact with the hands, that tend to injure and destroy it To protect objects from these influences, one among the many means adopted is to coat them with some preservative that is

impermeable to moisture and acid. In everyday life a common preservative is ordinary oil-paint or ordinary varnish, and in museums linseed oil is sometimes used to protect bronze and iron objects, and occasionally ordinary varnish is used for bones. All these substances, however, are too crude and too disfiguring to be employed on objects of art, and fortunately there are excellent substitutes that are almost colourless Among these, two stand out as much superior to the rest, namely, one a solution of celluloid in amyl acetate or in acetone or in a mixture of amyl acetate and acetone, and the other a solution of cellulose acetate in acetone Celluloid is not very soluble in amyl acetate, though sufficiently so for most purposes, and if a stronger solution is required acetone or a mixture of amyl acetate and acetone is used. Acetone, too, being more volatile than amyl acetate, dries more quickly Neither celluloid nor cellulose acetate, however, are perfect, as they tend to become very slightly acid with lapse of time, and cellulose acetate may also give an opalescent surface unless quite dry

To make these solutions, the best quality and the purest materials only should be employed The celluloid is rasped or cut

into small pieces and placed in a bottle, which is then almost filled with the solvent and well shaken from time to time. The celluloid will probably not all dissolve, but this does not matter and, as the solution is used, more of the solvent should be added. The cellulose acetate will already be in the form of powder, but as it generally contains moisture it should be well dried before use. It will be found that solutions of almost any consistency can be made, but none thicker than a thin syrup will be required. Such solutions will contain from about 1 per cent. to about 5 per cent. of the celluloid or cellulose acetate, they are colourless, and unless used too strong do not impart any gloss to the object treated The film produced is tough, elastic, colourless, transparent, and not affected by moisture Celluloid gives a slightly better result than cellulose acetate

Other colourless varnishes that may be mentioned are (*a*) a solution of dammar resin, generally wrongly called "gum" dammar, in benzol or in petroleum spirit, (*b*) a solution of mastic resin in alcohol, and (*c*) a solution of bleached shellac in alcohol

CHAPTER III

APPLICATION OF METHODS TO SPECIFIC MATERIALS

The application to specific materials of the methods already outlined will now be described, the materials being treated in alphabetical order.

ter The name alabaster is applied to two very different materials, one sulphate of lime and the other carbonate of lime, one form of each being very similar in appearance Which of these two substances has the prior claim to the name will not be discussed, but although the ancient Egyptians occasionally used sulphate of lime for making small objects, the term alabaster in Egyptology always means carbonate of lime, and it is this material that was employed for sarcophagi, statues, statuettes, vases, and other objects. Occasionally it is called "Oriental" alabaster, or sometimes "onyx marble," but both names are bad. Geologically the material is calcite, though sometimes

erroneously termed aragonite, a material of similar composition, but different crystalline form and different specific gravity. Although aragonite may occur it is not common, and all the specimens of Egyptian alabaster examined by the author have been calcite.

The first step in the cleaning of alabaster is careful washing with good quality soap and warm water, aided if necessary by a small and not too hard a brush All ordinary dirt and even most unpromising-looking stains may be removed in this way. After washing, the object should be well rinsed in clean water and placed on a clean cloth to drain and dry.

If there are stains that water will not remove, petroleum spirit, alcohol, acetone and benzol should be tried in the order named, that particular reagent being used that gives the best results.

If the object is a vase, it may contain decomposed organic matter, which unless removed may detract very much from the appearance, as the walls of vases are frequently sufficiently thin and translucent for a dark material to show through. As much of the contents as possible should be scraped out with a piece of wood and, unless

the material is definitely of a fatty nature, the vessel should be filled with warm (not hot) water and left to soak, and afterwards washed out repeatedly with warm water. A piece of cloth tied to the end of a stick, or a brush, such as is used in chemical laboratories for cleaning bottles, will be found useful

If the contents of a vase are of a fatty nature, or if water will not remove them, petroleum spirit, alcohol, acetone and benzol should be tried in the order named, the one which gives the best results being used. For petroleum spirit to be effective the material must be thoroughly dry, and therefore, if water has been used, this must be removed, and the best and quickest way of doing this is to rinse with alcohol, which takes up the water, drain and place in a warm place to dry, alcohol drying much quicker than water Petroleum spirit is satisfactory for fatty matter, alcohol for resinous matter, and acetone and benzol for many miscellaneous materials of an organic nature Considerable time and patience are frequently required to clean the inside of a vase

Acids must never be employed to clean alabaster, as they act upon and dissolve it.

Occasionally, round the top of an alabaster vase, there may be the remains of cementing material used to fasten on a lid. This is frequently beeswax or resin, and it is generally brittle and the greater part may readily be removed with a penknife. It should not be forgotten, however, that alabaster is a fairly soft material, and is easily cut or scratched, and when it has been in contact with organic matter of an acid nature, such as decomposed fatty matter, it becomes very soft and friable. If a knife is used, therefore, great care must be taken to avoid injuring the surface of the alabaster, and no attempt should be made to remove the last traces of the cementing material in this way, as it is almost impossible to do so without damage, the final stages of the cleaning being done by means of a solvent, such as chloroform for beeswax and alcohol for resin. Other solvents, among which are acetone, petroleum spirit and hot alcohol, will also soften beeswax, but will not dissolve it, and might be used when chloroform is not obtainable. The solvent is applied with a rag or brush, and the cement when softened may be scraped off with a piece of bone or wood, such as a small paper-knife.

Alabaster may be repaired with celluloid

cement in the case of small articles or with plaster of Paris for large objects. Missing parts may be replaced by plaster of Paris, which when dry is treated with celluloid, cellulose acetate, paraffin wax or stearine, as already described [1]

nd sins

Since amber is a fossil resin any particular piece from a tomb had been buried for geological ages before it was found and used by man, and therefore burial for a few thousand years more does not usually affect it, and it is generally in good condition, though sometimes dirty It is best cleaned by careful washing with good quality soap and warm water, aided by gentle rubbing with the fingers, followed by rinsing in clean water and drying.

Resins, other than amber, are often very brittle, and may be too tender to bear much treatment. Washing in warm water or cleaning with a damp camel-hair brush may however be tried, but should not be persisted in unless it is manifest that no harm is being done

Organic solvents (alcohol, acetone, benzol) should on no account be employed for cleaning amber or other resins, as many of them soften and dissolve resin This

[1] Pp 19–22.

solvent action may be utilized if, as sometimes happens, the surfaces of resin beads or other objects are disintegrating and flaking off. In such cases the object should be sprayed repeatedly with alcohol or acetone, either of which will cause the loose surface to become sticky and to adhere again.

Amber and other resins may be repaired with celluloid cement, or in the case of resins other than amber (amber being too insoluble), by moistening the broken surfaces with alcohol or acetone and then pressing them tightly together.

In connection with resin, the black varnish-like coating on many wooden funerary objects from ancient Egypt, which is generally wrongly termed bitumen, pitch or tar, may be mentioned. This material is a naturally black resin of a lacquer-like nature, which often is not very adherent, but tends to flake off It may be fixed and made to adhere again by spraying repeatedly with alcohol or acetone

ts and Work

Reeds, rushes and the stems of water-plants of various kinds, including papyrus, have been employed from very early times for making baskets, boxes, sandals and other objects. Such articles become very dry and brittle with lapse of time, but otherwise

are generally in a fairly good state of preservation.

If the condition of the object will allow, superficial dust and dirt may be removed by gentle blowing with a small pair of bellows or careful brushing with a small soft brush. In the case of very fragile objects, the careful application of petroleum spirit with a small camel-hair brush will be found helpful for cleaning, and a brush thus moistened may often be used when a dry brush would cause damage. Water should not be used.

Objects of the kind under consideration may be strengthened and preserved by saturating them with melted paraffin wax. The material, being absorbent, takes the wax well, and if this is applied quickly and very hot no excess will be visible on the surface The colour will be darkened somewhat, but the result is not unpleasing, and the object will be firm and will last indefinitely Excess wax may be removed in the manner already described [1]

ds Beads are of so many different kinds and vary so much in the material of which they are made that no general directions for treatment can be given.

[1] P. 21.

As a rule all beads, with the exception of those of wood and of resin, will stand washing with soap and warm water. Gilt wooden beads, which occur occasionally, and resin beads, unless in bad condition, may be cleaned with a damp camel-hair brush [1]

The holes in beads may be freed from dirt and old thread by means of a thin piece of wire for the larger and more solid beads and with a stiff bristle for smaller or more fragile ones. In cases in which the hole is solidly blocked up and the blocking material is very hard, great care is needed not to split the bead or not to chip the edges of the hole Damage, however, may generally be avoided by well soaking the bead in water to soften and loosen the obstruction before using the wire or bristle.

Faience beads, with which may be included faience pendants for necklaces, often have not been well glazed originally, and the glaze may be decomposed with the formation of a whitish coating on the surface All such objects should be well soaked in repeated changes of pure water until free from salt, and during soaking they should be removed from the water from time to

[1] See also "Amber and other Resins."

time and carefully brushed with a small brush.[1]

Great care is necessary in handling faience pendants, as the eyehole is easily damaged. When the projecting piece containing the eyehole breaks off this may be refastened in place with celluloid cement, but if the eyehole itself breaks the best remedy is to make a fresh one by cementing on a small bead of the requisite colour.

Beadwork when found is often in a fragile condition, owing to the material on which the beads have been sewn, or to the thread used, having perished In such cases it may be consolidated by treatment with melted paraffin wax, as originally described by Flinders Petrie If the wax is required to soak well in it should be applied very hot, but if much penetration is undesirable, as likely to cause the beads to adhere to objects below, the wax should be almost on the point of solidification before use. Excess wax may be removed as already described[2]

ay Only unbaked clay will be considered, baked clay being dealt with as pottery Clay objects include moulds, seals and inscribed tablets As clay falls to pieces when wetted it cannot therefore be washed

[1] See also "Faience." [2] P 21

After removing superficial dust and dirt by blowing or brushing, clay objects should be hardened by baking. The fact that the appearance is altered somewhat and the colour changed should not be allowed to stand in the way of treatment, as the life of dried clay is very short and baking is the only satisfactory method of prolonging it. With a little experience or by means of preliminary experiments, aided by Seger cones or pyrometers, the best temperature and the necessary time for the baking can be found within narrow limits. Too great a temperature and too sudden a rise of temperature should be avoided. For small objects a gas or electric muffle furnace similar to those used in chemical laboratories will be found satisfactory

After baking, clay objects if necessary may be soaked in water to remove salt or treated with dilute hydrochloric acid to remove concretions of carbonate of lime If this be done, the objects must afterwards be soaked in repeated changes of water until on testing no trace of acid can be found The object is then slowly but thoroughly dried Any crystals of sulphate of lime on the surface will be dehydrated and fall to powder during baking.

Broken objects may be repaired (after baking) either with celluloid cement or with plaster of Paris suitably tinted. Missing parts may be replaced by tinted plaster, which is afterwards treated with celluloid, cellulose acetate, paraffin wax or stearine, as already described.[1]

ce By faience is meant Egyptian faience This consists of a highly siliceous body coated with glaze which is generally coloured and is often blue or green

The glaze of faience is particularly liable to disintegration. Occasionally there is a cracking and partial peeling of the whole depth of the glazed surface, leaving bare patches of the body exposed This is caused by a different rate of expansion and contraction between the glaze and the body There is no remedy, but fortunately it is not progressive, and patches only of the glaze fall off When the pieces of fallen glaze exist they may be cemented in place again with celluloid cement As a rule it will be found that the pieces are larger than the place from which they have fallen, owing to the body having contracted or the glaze having expanded, but with care they may be adjusted until they fit by means of a small

[1] Pp. 19–22.

fine file or with fine emery paper moistened with paraffin oil (kerosene).

Generally the decomposition of faience takes the form of a disintegration of the glaze accompanied by a white crystalline deposit on the surface This deposit is ordinarily highly siliceous, but frequently contains also small proportions of carbonate of soda and common salt, with occasionally sulphate of soda. The carbonate of soda is formed from the alkali of the glaze and the carbon dioxide of the air, and any common salt or sulphate of soda present originate in the natron used for making the glaze, in which they occur as impurities. This disintegration is very unsightly, and results in the destruction of the surface and the disappearance of the colour. Sometimes, however, the colour disappears or changes without any signs of disintegration of the glaze, thus blue becomes green or fades to white and green turns brown

The phenomena described are manifestly caused by some chemical decomposition having taken place in the glaze The agents responsible are moisture and carbon dioxide The mechanism of the action is probably much as follows The glaze is porous and contains a large proportion of alkali, mois-

ture containing carbon dioxide in solution condenses on the surface and is absorbed, this decomposes the alkaline silicates, the result being a disintegration of the glaze with the deposition on the surface of the products of decomposition, sometimes in the form of a white or slightly tinted loose film, which eventually scales off or may be removed by brushing or scraping, but often as a white coating of which only a small part can be removed, the greater part consisting of strongly adherent crystalline siliceous material Concurrently with this disintegration the material which gives the colour to the glaze may undergo chemical change and, as already stated, blue may become green or white and green may turn brown. Frequently, however, much of the colour is merely obscured and not destroyed

Although the glaze of faience is essentially glass, it is much more subject to disintegration than glass, probably because it has been fused at a lower temperature and therefore is more porous, and, for the same reason, may contain common salt and sulphate of soda, both derived from the natron used in the manufacture and both of which would disappear at a higher temperature.

In addition to the disintegration described,

which is largely chemical and from within, although initiated and aided by outside influences, there is another form which may occur which is wholly physical and from without. This is confined to objects which have been in contact with salt and which have been alternately wet and dry. In this case the faience, which is very porous, becomes impregnated with a solution of salt, and when the object dries, the salt is brought to the surface by capillary attraction, and as the water holding it in solution evaporates, the salt crystallizes, and by the mere act of crystallization forces off particles of the glaze

The best method of treating faience is as follows

1. Wash well with warm water and soap, using a small sponge or soft brush. This removes superficial dirt

2 Soak well in repeated changes of water until free from sulphate of soda and common salt. Gently boiling the water will help by the mechanical stirring set up, but boiling water has no great advantage over warm water as a solvent for common salt. When in the water the colour of the glaze will appear very bright, and any white surface deposit will be hardly visible.

3. Dry thoroughly but slowly, and at not too high a temperature. The result will be disappointing, since any white deposit, in so far as it consists of siliceous material, will now be apparent again and will obscure the colour of the glaze.

4. If there is still a white or tinted coating on the surface, brushing with a small hard brush or rubbing with very fine emery paper should be tried Occasionally much of the film may be removed in this way, though more frequently the treatment is without effect. Rinse well in water and dry thoroughly.

5. Warm.

6 Rub over with a very small quantity of white vaseline, applied with a soft cloth or with the fingers, in such a manner that no excess vaseline remains on the surface. Although yellow vaseline is better than white vaseline for many purposes and is less liable to contain acid, yet the yellow variety should not be used in this instance, because if the glaze is coloured blue, as is frequently the case, the yellow of the vaseline would tend to give the blue a greenish tinge The white deposit will become almost invisible and the original colour will once more be seen, as

was the case when the object was soaking in water. Olive-oil,[1] poppy seed oil [1] and melted paraffin wax [2] have all been recommended for a similar purpose, but vaseline is the most satisfactory.

The explanation of the action of the vaseline, oil, or wax is that the white appearance of the faience is due to the reflection of light from the irregular surfaces of the crystalline deposit, but when the air is removed and replaced by a substance, such as one of those mentioned, the refractive index of which is approximately that of the material itself, the crystals become almost transparent and the colour of the glaze underneath is seen through.

The use of acid, caustic soda, or carbonate of soda for cleaning faience is usually unnecessary and not to be recommended, partly because these reagents tend to act upon the glaze and to destroy it, and partly because they are very difficult to remove afterwards, even by repeated washing.

Broken faience is best repaired with celluloid cement Missing parts may be replaced by plaster of Paris.

[1] *The Preservation of Antiquities.* F. Rathgen, Cambridge, 1905, p 151

[2] *Methods and Aims in Archæology.* F. Petrie, London, 1904, p 89.

rs
ir

Feathers become very tender and brittle with age, but may be strengthened by spraying with a very dilute solution of celluloid or of cellulose acetate. Care must be taken that the liquid is delivered in a very fine spray and that the feathers do not become saturated with the solution, otherwise the finer portions will stick together and the appearance will be spoiled. A spraying apparatus, such as is used for the throat, will be found satisfactory.

Hair is very resistant to ordinary influences of decay, and as a rule will not require treatment.

Both feathers and hair are very liable to be attacked by insects and should therefore be kept in cases that will exclude these pests, they should also be examined periodically, and naphthalene should be kept in the case A further safeguard is to spray them with a solution of mercuric chloride (corrosive sublimate) in alcohol If actually attacked by insects they should be fumigated with carbon disulphide in the manner already described [1]

Gesso and Plaster

The terms "gesso" and "plaster" are used very loosely and are often applied

[1] P 28

indiscriminately to very different materials. The Egyptian materials will be taken as the types.

Gesso Gesso was largely employed by the ancient Egyptians for covering wood before painting or gilding, and was applied either directly to the wood or to a layer of canvas-like material, which was glued to the wood. It is composed of whiting (carbonate of lime) and size or glue Being a soft material, gesso is easily damaged mechanically ; it is also readily disintegrated by water, but is rarely subject to chemical alteration or decomposition on keeping or exposure. The great danger to which gesso is liable arises from alteration in volume of the wood to which it is attached, contraction or splitting of the wood, caused by drying, results in the gesso becoming loose or breaking off, especially at joints and corners

Gesso, which is gilt, may be cleaned with a damp sponge or a small, soft, damp brush. A little soap dissolved in the water or a little ammonia added generally helps If the gesso is cracked, or flaking off, or in bad condition, the minimum amount of water should be used, and care should be taken that none enters the cracks or penetrates under the gilt surface, or it will disintegrate

the gesso. In very bad cases water should be avoided altogether and petroleum spirit used instead.

Gesso that is painted, but not varnished, may be cleaned either with petroleum spirit or alcohol, using a small soft brush, but not with water, as the paint would come off if wetted.

Gesso that is both painted and varnished may be cleaned with a damp sponge or a damp brush or with petroleum spirit but not with alcohol, as this might soften or dissolve the varnish If water is used care should be taken that none enters any cracks that may be present or penetrates under the varnish, since, as already mentioned, this would cause disintegration of the gesso

When gesso, which is gilt and varnished, or painted and varnished, is in good condition, no treatment beyond cleaning will be required, but when painted and not varnished, the paint, which rubs off readily, may be made to adhere again by spraying with a dilute solution of celluloid or of cellulose acetate

Broken gesso may be repaired with celluloid cement Gesso in a bad state of preservation should be consolidated by impregnation with melted paraffin wax Before applying the wax the gesso should be

warmed if possible, and the wax should be put on very hot. When properly applied the wax will all sink in and will hardly be apparent, but should any excess remain on the surface in a manner to cause disfigurement, this may be removed by heat, as already described [1] Gilt and paint are both brightened by the wax

Blisters in gesso should be filled with melted paraffin wax by means of a pipette and, just before the wax hardens, the blister should be pressed down firmly with the hands.

Plaster By plaster is meant the various qualities of sulphate of lime ranging from crude gypsum to fine plaster of Paris. Plaster was employed in ancient Egypt for filling up holes and smoothing irregularities in stone, for coating walls before painting and for making moulds and casts.

Plaster, like gesso, is soluble in water, and therefore should never be wetted Superficial dust and dirt may be removed by blowing or brushing, any further cleaning being done by means of petroleum spirit or alcohol and a soft brush If painted, and if the paint shows signs of coming off, it should be sprayed with a dilute solution of celluloid or of cellulose acetate.

[1] P 21.

Glass is not the unalterable impermeable material generally supposed. This is especially true of ancient glass, which as a rule is softer, and was originally softer, than modern glass, on account of its containing a much larger proportion of alkali

The decomposition of glass is sometimes not more than a slight dimming of the surface, but more generally small particles scale off leaving the surface pitted, or the whole surface may crack and scale This latter condition is often accompanied by an iridescence, which is purely an optical effect produced by the breaking up of the white light as it is reflected from the numberless small colourless scales which result from the decomposition Occasionally glass may become so rotten that it falls to powder, but fortunately this extreme form of disintegration is very rare

Apart from the chemical decomposition of the glass itself, the colour often undergoes change Thus white glass of ordinary quality containing manganese compounds becomes coloured when exposed for some time to strong sunlight This colour varies from a very slight to a deep amethyst colour. In Egypt it is a matter of common observation

to find on the desert, in the neighbourhood of towns, pieces of what has been white glass coloured in this manner. The depth of colour appears to vary with the time of exposure. Other colour changes may also occur in glass, for example, the blue colour of old Egyptian glass, when this is due to copper and not to cobalt, sometimes changes to green and the colours of stained-glass windows undergo slight changes of tint as the result of long exposure, which generally mellow them and add to their beauty.

The decomposition of glass is due, in the first place, to the fact that the glass contains an excess of alkali, and in the second place, to the further fact that glass is hygroscopic and condenses on its surface moisture from the atmosphere, containing carbon dioxide in solution The result is a chemical decomposition with the formation of carbonate of soda and the separation of silicate of lime and probably some silica

The only cure for glass that is disintegrating is to soak it in repeated changes of warm water until free from all soluble salts and free caustic or carbonated alkali, allow it to drain, soak in alcohol, dry thoroughly, and then coat it with a transparent varnish, such as a solution of celluloid or of cellulose

acetate. Any necessary repairs may be made with celluloid cement.

The old Egyptian red glass, which is coloured with copper, is liable to surface decomposition, with the result that it becomes covered with a green coating. This is very resistant to treatment, but may generally be removed by boiling in strong caustic soda solution followed by thorough washing in water until all traces of the soda are removed. The surface, however, will be left deeply pitted.

Ivory, Bone and Horn

ory The condition of ivory objects as found varies considerably, some being in a very good state of preservation, while others are so brittle as to make even handling difficult, and many ivory objects from Egypt, in consequence of containing salt, are particularly delicate

When in good condition, ivory may be cleaned by means of a damp sponge or damp brush, but it should not be wetted much as it is very liable to split into flakes Occasionally, however, ivory, and even the most ancient ivory, may be soaked in water without damage, and this treatment is often

very desirable in order to remove salt, but it cannot be adopted as a routine practice, owing to the uncertainty of the results Although the appearance and condition of an object are some guide to its probable behaviour in water, it is generally impossible to be certain beforehand that a particular piece of ivory will stand soaking, and the safe rule, therefore, is to avoid water. In the exceptional case in which the risk is taken and an ivory object is soaked, this should first be done in ordinary pure water and afterwards in distilled water, followed by alcohol and slow drying without artificial heat

After cleaning, ivory may be strengthened by spraying or brushing with a solution of celluloid or of cellulose acetate. Even using a dilute solution a slight glaze may be produced, but this is not objectionable, and gives the effect of the polish usually seen on ivory objects, but much glaze should be avoided Excess glaze may be removed by means of amyl acetate or acetone applied on a tuft of cotton-wool

For ivory in bad condition there is only one remedy, namely, impregnation with celluloid, cellulose acetate or melted paraffin wax, and this must be done without any attempt being made to remove any salt

present. Before treatment the object should be cleaned as well as possible by gentle blowing and brushing, followed by further brushing with a small soft brush damped with alcohol. Sometimes the alcohol will loosen adherent earthy matter, which may be removed The object is then slowly dried and, if celluloid or cellulose acetate are used, these are applied either with a small camel-hair brush or in the form of a spray If wax is employed, the object, previously warmed, if possible, is placed on supports in order that it may drain, and treated, first on one side and then on the other, with hot melted paraffin wax The wax should be applied quickly in a thin stream, which is best done by means of a pipette If the temperature of the object and of the wax are satisfactory the wax sinks well in without leaving any excess visible on the surface If, however, excess wax is left, this may be removed in the manner already described.[1] One objection, though not a serious one, to the use of paraffin wax is that it may slightly darken the ivory.

Not infrequently ivory objects found in Egypt are coated with a hard incrustation of carbonate of lime, or of sand and earth

[1] P. 21.

bound together by carbonate of lime. This can only be removed by acid, hydrochloric acid being the best. The acid should be very dilute (about 1 to 2 per cent.), and is best applied by brushing it repeatedly over the incrustation with a camel-hair brush. After treatment it is essential that every trace of acid should be washed out by soaking the object in repeated changes of water, until on testing the washings are found to be acid free. It is only ivory in an exceptionally good state of preservation that will stand such treatment.

Ivory objects may be repaired with celluloid cement.

Bone Bones and bone objects may generally be cleaned by washing with soap and warm water. If salt is present this may be removed by soaking in repeated changes of water until it is all dissolved out, which may be ascertained by testing The object should be dried slowly. If the bone is cracked, or is not in good condition, it may be wrapped tightly in gauze or tied round with fine string before soaking

For repairing small bone objects, celluloid cement may be used, and for large objects glue or plaster of Paris After cleaning and repairing, bones and bone objects should

be brushed over with a solution of celluloid or of cellulose acetate. The practice sometimes employed of coating bones with ordinary painters' varnish should never be followed, as it can only result in discoloration and disfigurement.

Bones and bone objects in a fragile condition should be treated with celluloid, cellulose acetate or melted paraffin wax in the manner described for ivory.

rn As a rule horn requires little or no treatment beyond cleaning, which may generally be done with warm water. Horn, however, is subject to the attacks of insects, and even ivory and bone are not exempt, though less liable than horn to be attacked The best preventive, and also the best remedy if the object is already attacked, is to spray or paint it with a solution of mercuric chloride in alcohol This solution is very poisonous and must be used with care Horn, if broken, is best repaired with celluloid cement or glue

Jewellery and Enamel

ry Ancient jewellery is generally made of gold or silver, or of these metals inlaid with stones, faience or glass.

Gold or silver articles, when not inlaid,

should be treated as described later when dealing with metals.

For inlay, whether with precious stones, semi-precious stones, faience or glass, soaking and washing in warm water, aided by a little good quality soap, together with gentle rubbing with a soft brush or soft cloth, will generally be sufficient. Sometimes faience and glass inlay has a coating on the surface which may be either a product of the decomposition of the material or may be largely the glue used as a cement which has come from the under side of the inlay. In the former case very little can be done beyond washing with water and when dry coating with a thin film of some transparent varnish, such as a solution of celluloid or of cellulose acetate In the latter case the deposit can generally be removed by means of repeated applications of warm water, aided by gentle scraping

One of the guiding principles in the cleaning of inlaid jewellery is to ascertain, if possible, the nature of the cementing material holding the inlay in place, and not to use any reagent that will soften or dissolve it. For example, if the cement consists of resin or contains resin, as is often the case, alcohol should not be used for cleaning, if the cement contains whiting or gypsum,

prolonged soaking in water must be avoided.

Acids and alkalies should never be used, for not only may the cement be dissolved, but some of the materials forming the inlay may be attacked, thus lapis lazuli, malachite and calcite are all acted upon by acids and turquoise is affected by alkalies

To repair jewellery, when the inlay has come loose or fallen out, celluloid cement is recommended.

el Enamel is a vitreous material fused by heat on to a metal base, the difference between enamel and inlay being that the former is never a natural stone, but always a kind of glass (paste) fused in position, while the latter, which may consist of a variety of materials, is cemented in and never fused

Enamel may be cleaned with a little warm water and soap and a soft brush

For enamel that has cracked and is separating from the metal base, Dr Alexander Scott [1] recommends treatment with a solution of Canada balsam in benzol, after partial exhaustion of the air, so that the balsam may penetrate well This treatment has been adversely criticized on the

[1] *The Cleaning and Restoration of Museum Exhibits*, Dept. of Sci and Ind. Research, London, 1921

grounds that the balsam will darken in colour and will eventually crack and break up.[1] It is doubtful, however, whether any better method can be found

Leather Leather is very subject to deterioration It readily dries and becomes brittle, and there is evidence that occasionally when exposed for long periods of time to a moist heat in a closed tomb it becomes viscous and "runs," although when found it may be hard, brittle and lustrous, and very like pitch in general appearance. When in this condition it is softened by, and largely soluble in, water (as much as 85 per cent being soluble in one specimen tested), and may be removed from objects to which it is adhering by means of hot water. It is, however, beyond treatment

To keep leather in good condition, and to restore to some extent any suppleness it may have lost, oil or grease should be employed, but these are only of use if the deterioration has not proceeded too far Any oil that readily becomes acid, such, for example, as neat's-foot oil and olive-oil, which are sometimes recommended, should be avoided, but castor oil, lanoline, sperm oil and vaseline may all be used The oil or

[1] *J Royal Society of Arts*, March 24, 1922, p. 336

grease chosen should be warmed before use and should be smeared on the leather and well rubbed in, if the condition of this will allow, the treatment being repeated from time to time. When the leather is too brittle to bear much handling, the object may be soaked in the oil or the latter may be applied with a soft brush The author has found a solution of lanoline in petroleum spirit, which may be sprayed on, sometimes gives good results.

Leather is subject to the attacks of various insects, particularly cockroaches and silver fish These may easily be kept at bay by well-fitting show-cases, by frequent moving and dusting of the objects, and by spraying with a solution of mercuric chloride in alcohol, which is very poisonous and must be used with care

Metals

The metals which will be dealt with are gold, silver, copper, bronze, iron, and lead

d When gold is very pure it is a bright yellow colour and does not corrode or even tarnish and therefore requires no cleaning beyond the removal of dirt, which may be done by means of soap and warm water,

aided by a soft cloth or small brush. The brush should not be hard, or it may scratch the gold, pure gold being soft and easily scratched If there is any red patina on the gold, rubbing or brushing should be done with care, otherwise this patina, which is not only evidence of age, but also adds to the beauty of the object, may be destroyed.

Gold, however, is rarely pure, but generally contains small proportions of other metals, chiefly silver, copper and iron, which undergo chemical change and give rise to a surface discoloration or tarnish.

To clean gold when tarnished, it should first be washed with soap and warm water, with gentle rubbing with a soft cloth or brushing with a soft brush, and then treated with ammonia solution (10 per cent), which is applied with a rag or camel-hair or similar brush. In the rare cases in which ammonia is not successful, cyanide of potassium should be tried, as this will remove tarnish due to sulphide of silver and sulphide of copper, which are not soluble in ammonia. This reagent should only be employed in very dilute solution (5 per cent.), as it acts upon and dissolves gold when used too strong or if left in contact with the gold too long After treatment the object must

be thoroughly washed in water and carefully dried.

Occasionally on the surface of gold there are patches of reddish-brown discoloration caused by organic matter This is not soluble either in ammonia or in cyanide of potassium, but can usually be removed by the careful use of plate powder, such as whiting or jewellers' rouge, or by heating, if the nature of the object will permit.

Sometimes on ancient Egyptian gold objects there are incrustations of carbonate and sulphate of lime. No attempt should be made to scrape these off, as this would scratch and disfigure the gold, but any such deposits may be completely removed by soaking the object in a dilute solution of hydrochloric acid, which is without action on gold The acid must be followed by thorough washing in pure water and drying.

A number of objects in the Cairo museum, which at first were thought to be of solid gold, were much defaced by incrustations, which appeared to be metallic, but which on chemical analysis were found to consist of chloride of silver in the form of "horn silver." It was further found that the objects were not of solid gold, but originally

had been of silver coated with thin sheet gold, and the silver had become partly, and probably largely, converted into chloride, and it was from this that the incrustations had been derived. As ammonia is one of the best solvents for chloride of silver and could not injure the gold, the objects were soaked for several days in strong ammonia. The chloride of silver on the surface was entirely removed, that in the interior, being protected by the gold, was not noticeably attacked and the objects were left in excellent condition.

Gilt objects are cleaned in the same manner as those of solid gold or sheet gold, but when the gilt is thin, great care is needed to avoid damaging the surface and the cleaning should be done with a small soft brush. As old Egyptian gilt is generally on gesso, the precautions mentioned when dealing with this material [1] should be observed. Sometimes on the surface of gilt there is a characteristic reddish-brown deposit, which is confined to the vicinity of cracks and broken edges. This is largely an exudation of glue from underneath, and it may be removed by frequent applications of warm water used with a small piece of sponge or a soft brush

[1] P. 50.

Silver as employed for making jewellery, ornaments, plate and other objects is never pure, but always contains other metals, notably copper.

Antique silver, and particularly old Egyptian silver, varies very much in its state of preservation, the severity of any corrosion ranging from a slight surface discoloration or tarnish to a condition so bad that the metal has wholly disappeared and has been replaced by the compounds resulting from the chemical changes that have taken place. Naturally these different conditions require different methods of treatment As it is impossible to describe separately each of the infinite stages or degrees of corrosion, these will be divided for the sake of convenience into three main groups, namely, (*a*) tarnish, (*b*) slight corrosion, and (*c*) considerable corrosion. These will now be considered.

Tarnish.—This is a very thin, grey or black film on the surface of an object, which otherwise is in excellent condition and perfectly sound. On ancient objects the film ordinarily consists of chloride of silver, but occasionally may be sulphide of silver, together with a little sulphide of copper, or a mixture of chloride and sulphide. On modern silver, or on ancient silver that has

acquired a recent tarnish, the film is usually sulphide.

The chloride has been caused by the action of a slight amount of common salt, such as might be present in the atmosphere, thus, for example, in Egypt salt occurs almost everywhere, in the limestone rock in which so many tombs are made and in the desert sand, and hence its presence in the dust in the air is not surprising. Salt also occurs in the air near the sea-coast. Sulphide that has been acquired anciently has come from contact with decaying organic matter containing sulphur and modern sulphide from exposure to an atmosphere contaminated with sulphur compounds derived from the burning of coal or coal gas.

A surface discoloration of the kind described may readily be removed, chloride of silver being soluble in ammonium hydrate (ammonia solution) and also in cyanide of potassium, and both sulphide of silver and sulphide of copper being soluble in cyanide of potassium.

Since the tarnish on ancient silver is commonly due to chloride and rarely to sulphide, ammonia therefore will generally remove it and, as ammonia is more easily procurable and less dangerous than cyanide

of potassium, which is very poisonous, ammonia is to be preferred, a solution containing about 10 parts of strong ammonia to 100 parts of water being used. Ammonia, too, has the advantage of being almost without action on silver, and although it acts upon any copper present in the alloy this action under the conditions in which it is used is negligible. In the rare cases in which the tarnish is due to sulphide, cyanide of potassium (5 per cent solution) must be used. This acts slightly upon silver, but if employed in dilute solution, and if the object is well washed afterwards this action may be disregarded. The ammonia, or cyanide, is best applied by means of a tuft of cotton-wool or with a small soft rag. After cleaning, the object must be thoroughly washed with pure water and carefully dried.

Slight Corrosion.—This, though largely consisting of chloride of silver, also contains compounds of copper originating in the copper alloyed with the silver When the silver is of poor quality and contains a large proportion of copper the corrosion may be of a green colour, though this is unusual As already stated, two excellent solvents for chloride of silver are ammonium hydrate (ammonia solution) and cyanide of potassium,

and these have already been recommended for use in removing tarnish. But with any corrosion greater than tarnish, simple rubbing the surface of the object with a dilute solution of the solvent would be useless, and it becomes necessary to soak the object in the solution and to leave it for several hours at least and possibly for days. Under these conditions the use of cyanide of potassium is not advisable, for not only does it attack and dissolve silver to a slight extent, but it also dissolves the gold of any gilding that may be, and often is, present on silver objects of certain kinds and periods.

Ammonia solution is almost without action on metallic silver under ordinary conditions, and if the silver of which objects of art are made were pure, treatment with ammonia would be an invaluable remedy for corrosion, but the metal is not pure silver but essentially an alloy of silver and copper, and unfortunately ammonia attacks and dissolves copper, even when alloyed with other metals, and the action, though only slight with alloys containing less than about 20 per cent. of copper, is considerable in the case of alloys containing a larger proportion of copper. Since it is impossible as a rule to know the composition of the

alloy operated upon, the use of ammonia as a routine practice cannot be recommended, though it is an exceedingly valuable reagent that should not be neglected in the case of high-quality silver that has become corroded. To avoid the solvent action of ammonia this may be mixed with ammonium sulphite or sodium sulphite, as recommended by Dr. Alexander Scott,[1] both of which compounds are reducing agents and act upon the chloride of silver, converting it back again into the metallic state A very small proportion of either copper sulphite (cuprous) or copper sulphate may be added, as without a copper compound the whole of the chloride of silver is not reduced. There may be, however, sufficient copper present from the corrosion The object is immersed in the solution, which is then heated

One of the best reagents for the removal of slight corrosion from silver is hot formic acid, recommended by Dr Alexander Scott [2] The object is placed in a glass, glazed earthenware, or enamelled-iron vessel, metal being avoided A solution of formic acid in water, sufficient to well cover the object,

[1] *The Cleaning and Restoration of Museum Exhibits*, Dept of Sci and Ind Research, London, 1921. [2] *Ibid.*, 1921 and 1923

is added and the solution heated. The strength of the acid may vary from 5 to 25 per cent, but it is usually better to begin with about 10 per cent. The object is allowed to remain for several hours, when it is taken out and examined. If the action is not complete the object is replaced, the strength of the acid being increased if necessary The acid decomposes the copper compounds present and also a portion of the chloride of silver, with the result that, although the whole of the corrosion may not be decomposed, what is left is rendered less adherent and generally either falls off or may be brushed off while wet with a small soft brush The acid has no solvent action on the silver. After treatment the object must be thoroughly washed and carefully dried Formic acid is particularly valuable for the treatment of objects made of poor quality silver.

Considerable Corrosion —Corrosion may be so considerable that the object is coated with a thick lumpy crust, which hides all detail, not only of design, but also of shape, the general outline of the object only being recognizable, and it is sometimes impossible to know what the object is. Occasionally there may be a core of solid coherent silver

under the corrosion, but more often any silver remaining is in a very brittle and rotten condition, and frequently there is little or no silver left This crust, like that on less corroded objects, consists largely of chloride of silver mixed with small proportions of copper compounds derived from the copper contained originally in the silver Sometimes the chloride of silver is in the form of "horn silver," which is very adherent and which resembles lead somewhat both in appearance and hardness and which may be cut with a knife, but no attempt should be made to remove it in this manner, as the result would certainly be failure and probably disaster When the object has a core of silver left, whether this is solid and coherent or not, it may be treated as already described for slight corrosion, namely, either with hot formic acid or with ammonium sulphite and ammonia or sodium sulphite and ammonia, but more prolonged treatment is necessary than in the case of slight corrosion It is generally better, however, to commence by soaking the object in ammonia, a solution containing about 50 parts of strong ammonia to 100 parts of water being used, and to follow this by treatment with hot formic acid. Much of the corroded

material will either dissolve or will fall off the solutions, and the remainder may usual be detached while wet by gentle pickın with a small bone or ivory paper-knife similar instrument having a thin edge, may be brushed off. After experience the mechanical treatment of copper aı bronze objects there will be a great tempt tion to attempt to flake a silver object the same manner, but this must not on aı account be done, as it is never safe, and force whatever must be employed, otherwi damage will certainly result After treaı ment, the object should be well washed pure water and thoroughly dried.

If the silver under the corroded surfa is in a coherent solid state the result treatment will generally be satisfactoı and even if the silver core is brittle a rotten a satisfactory result may also obtained, if care is taken in handling t object during treatment and particulaı if no force is employed in removing a chloride left after treatment Unless, ho ever, great care is exercised the object w certainly break, as the silver has very lit strength or cohesion Occasionally the cor sion proves very obstinate, part only bei removed, and in such cases a satisfacto

result may be impossible and an improvement of the original condition all that can be obtained.

If an object, of which the walls were originally thin, is much corroded, it is certain that little or no metallic silver is left, and in such a case it is almost inevitable that during treatment the object will break or may even fall to pieces This possibility, therefore, must be faced, and a decision made whether it is better to leave the object untouched and corroded, with sometimes its very nature unknown, or to risk damage and even total loss, in the hope that something of interest, or beauty, or even of archæological value, such as an inscription, may be saved If it is decided to risk treatment, every care possible must be taken in handling the object, especially in the final stages With objects in this tender condition no attempt should be made to remove loosened corrosion except with a camel-hair or similar soft brush.

Hollow objects such as boxes, vases and bowls that are very thin and tender may be strengthened by being lined or filled with paraffin wax. This is best applied by means of a pipette, and should be on the point of solidification when used. If there are holes

in the object, through which the wax would run out, these should be stopped up from the outside with a thick coating of wax by means of a penknife, the wax being in the plastic condition that is found on the surface of a mass that is cooling After the wax core is finished, the surplus wax on the outside may readily be removed with a penknife, the blade of which is heated in the flame of a bunsen lamp or spirit lamp One great advantage of lining or filling an object with wax is the ease with which repairs may be executed. All that is necessary, if the loose piece is small, is to place it on the wax and touch it with the heated blade of a penknife, when it sinks into position If the loose piece is large, it is placed in position before the lining or filling is done, and is held in place by plastering over the join from the outside with plastic wax, then applying a thick lining of wax inside and finally removing the excess wax from the outside with the heated blade of a penknife.

For small repairs to silver objects celluloid cement will be found satisfactory, and, if the silver is not very coherent, coating it with celluloid solution will strengthen and preserve it, the silver sometimes absorbing a large amount of the solution

and onze The most important metal used in antiquity was copper, which at first was employed alone and afterwards in the form of bronze. This copper is never pure, but contains small proportions of other ingredients, the most common of which are antimony, arsenic, bismuth, iron, tin and sulphur. The total impurities generally amount to about 2 to 3 per cent., though sometimes they are more.

Bronze is essentially an alloy of copper and tin, with occasionally a little zinc. The proportion of the two metals in modern bronze is usually about 90 per cent of copper to about 10 per cent. of tin In ancient bronze the proportion of tin is not so constant as in the modern article, and varies from about 5 per cent to about 16 per cent , but frequently it is about the same as in modern bronze, namely, about 10 per cent. The impurities in ancient copper are naturally found also in ancient bronze, with sometimes the addition of lead, which may be present in proportions ranging from a trace to about 20 per cent. The advantage of bronze over copper is twofold firstly, it is harder than copper, and secondly, the melting-point is lower, thus enabling castings to be made more easily

Copper and bronze objects corrode very

readily, the compounds formed being basic copper carbonates,[1] which may be either green or blue in colour, copper oxides, of which there are two, one red and the other black, and in Egypt generally copper oxychloride (green), due to the action of salt.

aning of oper and Bronze

Various methods of cleaning are in common use which are not satisfactory and are not recommended. These include the use of (*a*) ammonia, (*b*) hydrochloric acid, and (*c*) sulphuric acid.

Ammonia.—Ammonia should never be employed, as its action is not limited to the corrosion, but extends to the metal itself, which it also attacks The results, too, especially on badly corroded objects, are not satisfactory.

Hydrochloric Acid—Although hydrochloric acid has only a slight action on the metal, it also is not satisfactory, one great objection to its use being the difficulty of eliminating all traces of it afterwards. This acid, too, produces on the object treated a white coating of cuprous chloride, which is difficult to remove.

Sulphuric Acid—Like hydrochloric acid, this acid has very little action on the metal if

[1] Often wrongly termed "verdigris," which is basic acetate

used cold and dilute, but the results obtained with it are not satisfactory, and it is an unpleasant and dangerous substance to handle.

Ammonium Chloride.—Ammonium chloride, both alone and mixed with small proportions of stannous chloride and hydrochloric acid, has been suggested by Dr Alexander Scott[1] Alone, ammonium chloride has a slight action on copper and bronze, and the results of its use are not very satisfactory, the object often acquiring a white or unpleasant grey colour, which is difficult to remove and, if much corroded, being only imperfectly cleaned. The yellow coating sometimes formed, and which consists of cuprous oxide in the colloidal form, is readily brushed off When the ammonium chloride is mixed with small proportions of stannous chloride and hydrochloric acid, the action on the metal is diminished and the results are much better, though frequently not so satisfactory as those obtained by means of an alkaline solution of Rochelle salt, also suggested by Dr Scott,[1] and which, in the author's opinion, is the best all-round method for general use Other methods recom-

[1] *The Cleaning and Restoration of Museum Exhibits*, Dept. of Sci. and Ind Research, London, 1921 and 1923.

mended, besides Rochelle salt, are treatment with acetic acid, reduction methods and mechanical methods. These will now be described.

Rochelle Salt.—The Rochelle salt method is carried out as follows: an alkaline solution of Rochelle salt (sodium potassium tartrate) is made containing 15 parts of Rochelle salt and 5 parts of caustic soda to every 100 parts of water. The object is immersed in this solution and left for some hours or for a day or two, as is found necessary, being taken out from time to time, rinsed in water and well rubbed with the fingers or brushed while wet with a small stiff brush, such as a tooth-brush or nail-brush, or even with a fine brass (not steel) wire brush, if after trial this is found not to scratch the metal The small compound bristle and brass-wire brush sold for cleaning brown shoes will be found useful. On removal from the solution the object will usually be found coated with a layer of red oxide which, unless very thick, will be removed, or largely removed, by the brushing, which may be supplemented if necessary by the mechanical treatment described later. The treatment of the object should usually be finished in a bath of fresh solution, the old solution being filtered and put on one side to be used as the first bath

of another object. After cleaning, the object must be thoroughly washed in repeated changes of pure water and carefully dried. The results are very satisfactory, even for badly corroded objects.

Acetic Acid.—Acetic acid when dilute has very little action on copper or bronze, it removes corrosion well, is easily obtainable, and is not objectionable to use. The object is immersed in a dilute solution of the acid (about 10 parts of the strong acid to each 100 parts of water) and is left for some hours and if necessary for several days, until all the green corrosion has disappeared, and only a coating of red oxide is left. It is then taken out, well brushed as previously described, and if necessary subjected to the mechanical treatment dealt with later It is finally repeatedly washed until free from all traces of acid and well dried. Formic acid is still more satisfactory than acetic acid, but its cost is considerably greater

Reduction—The methods of reduction depend upon the production of nascent hydrogen by the action of certain acids or alkalies upon certain metals There are many variants, but acids should always be avoided if possible, as they may attack the metal itself and are always difficult to

eliminate afterwards. The simplest and best method is to employ zinc and caustic soda. The details of the process are as follows take an iron saucepan or a porcelain basin and in this place a layer of granulated zinc On the zinc lay the object to be treated and on this more zinc until the object is completely covered. Add a dilute solution (10 per cent) of caustic soda, heat and allow to simmer gently for several hours When the object is removed it will be found coated with a black deposit. It is rinsed in water and well brushed while still wet with a brass-wire brush. If the action appears incomplete the object is replaced and the boiling continued for a further length of time Finally the object is thoroughly washed and well dried. The results of this treatment, although appearing satisfactory at the time, are often disappointing, as spots of green corrosion are very liable to appear later When this happens, the spots are well brushed with a brass-wire brush and the treatment is repeated, or, better, the object is treated with Rochelle salt as already described.

Mechanical Treatment—This is occasionally sufficient by itself, but more generally it will be found a useful auxiliary to the

chemical treatment, and may be used either before or after or both, according to the nature of the corrosion. It is best applied when the object is wet, either after merely rinsing with water when it is removed from the solution in which it has been treated or after well wetting it with water. If the object is dry the fine dust created is very objectionable and is also injurious to the lungs.

The method consists in flaking off the corroded surface with a very small chisel of the kind used by jewellers, or with a watchmaker's hammer or even with a penknife. Sometimes almost the whole of a corroded surface will flake off leaving the metal clean and free from corrosion The layer of red oxide of copper generally left after the Rochelle salt or acetic acid treatment may be rubbed or brushed off if thin, but if thick requires flaking off, when it readily comes away. As a rule mechanical treatment can only be applied to solid objects and not to those that are hollow or in a tender condition After mechanical treatment it is usually better to treat the object with Rochelle salt

Preservative Coatings.—Copper and bronze objects after being cleaned are frequently oiled or waxed This spoils the appearance and is unnecessary, as a colourless varnish,

of which several kinds are available, gives all the protection afforded by oil or wax and has the advantage of being scarcely visible. The best of these varnishes for copper and bronze is a dilute solution of celluloid or of cellulose acetate. If as the result of treatment a copper or bronze object is too bright, it is best left exposed to the atmosphere of an ordinary room for a time, when it becomes slightly tarnished, but if something more than this is required it may be given a black colour by immersing it in a dilute solution of sodium sulphide, after which it is rinsed in water and dried. The exposure to the air or the treatment with sodium sulphide must be done before varnishing, and before using either sodium sulphide or varnish the object must be freed from grease, which may be done by cleaning it with petroleum spirit With respect to patina in general it is only necessary to inspect any exhibition of modern sculpture or the excellent reproductions of antique bronzes made in Italy and Greece, to realize that a copper or bronze object may be given almost any kind of patina desired It should not be forgotten, however, that such patina is a surface corrosion which unless care is taken may gradually increase

A useful book on the subject is mentioned in the Bibliography, but the methods given in the ordinary household book of recipes should generally be avoided.

Bacteria.—Statements are sometimes made that the corrosion of bronze in certain cases is caused by bacteria This has never been proved and is most improbable, and all the observed facts in connection with such corrosion may be explained chemically.

Iron The fact that iron corrodes readily is a matter of common experience, and rusty iron may be seen almost everywhere. It is very noticeable, too, that on the sea-coast iron corrodes more quickly than inland.

The principal agents responsible for the ordinary rusting of iron are (*a*) moisture, without which rusting is impossible, (*b*) small proportions of impurities in the iron, which set up electrolytic action, (*c*) oxygen and carbon dioxide from the air, and (*d*) common salt from the ground in which the iron has been buried, from sea air or from dust in the atmosphere.

For cleaning iron from corrosion, when the condition of the object will allow, a simple and satisfactory method is first to remove as much of the rust as possible by brushing with a fine steel-wire brush or by flaking

with a small chisel or hammer as described when dealing with bronze, and then to place the object, surrounded by granulated zinc, in a solution of caustic soda, which is kept gently simmering, as already described for bronze. After treatment the object is rinsed with water and again well brushed with a steel-wire brush and finally thoroughly washed, quickly dried and coated with a preservative varnish as recommended for bronze. Many iron objects, however, are too thin or too much corroded to bear mechanical treatment or reduction, in some instance being only a mass of oxide, and, in such cases, all that can be done is to remove any salt present, well dry the object and coat it with a preservative varnish.

To remove salt, the object is first soaked in repeated changes of water until the washings show no salt on testing, it is then soaked or, better, boiled in a strong solution of caustic soda or of carbonate of soda, which is followed by prolonged boiling in water until all the alkali is washed out. The object is then thoroughly and quickly dried by heating and when cold coated with a preservative varnish. Linseed oil, which is often used for this purpose, causes great disfigurement, and is not as efficient as the

varnishes recommended, which also have the advantage of being colourless. All oils, fats and greases, except those of mineral origin, should be avoided on principle, as they are apt to develop acidity on keeping Vaseline and paraffin wax might be used, but are not needed, as a colourless varnish of the kind mentioned meets all requirements and is an equally efficient protection.

Lead Lead oxidizes quickly in moist air, but the result is only a superficial tarnish. Sometimes, however, ancient lead objects when found are coated with a thick white layer, often of a warty appearance, which consists largely of basic carbonate, with often a small proportion of chloride. Occasionally, too, lead is badly corroded, and even eaten into holes, by having been buried in damp ground containing nitrates.

The best way to clean lead objects is to commence by boiling in repeated changes of water in order to remove any chloride or nitrate present, followed, if there is basic carbonate, by soaking for some hours in a solution (10 per cent) of acetic acid, after which the object is thoroughly and repeatedly washed in water, dried and coated with a preservative varnish, such as a dilute solution of celluloid or of cellulose acetate.

Papyrus and Paper

apyrus

This is made from the fine layers of fibrous material obtained from the stem of the Egyptian papyrus plant. It was first employed as a writing material by the ancient Egyptians and afterwards by the Greeks and Romans.

Papyrus documents are often very dry and brittle and sometimes impregnated with salt

No attempt should be made to unfold or to straighten out papyrus while dry, as it would almost certainly break, but it should always first be damped with just sufficient water to render it pliable, which may be done by wrapping it in damp cloth or in damp white blotting-paper and allowing it to remain until the moisture has thoroughly penetrated

To remove salt, which should always be done when present, there is only one way, namely, to soak the papyrus in repeated changes of pure water until the washings when tested are free from salt With care, and unless the papyrus is in a very broken condition, water will not injure it, if the soaking is not too prolonged, the water, however, will be coloured brown and the papyrus will become lighter in shade To allow the water to penetrate freely the papy-

rus should first be moistened with alcohol. When wet, care must be taken that the ink is not rubbed during handling, as ink comes off very readily from damp papyrus. After removal from the water it is better to soak the papyrus for a few minutes in two changes of pure alcohol; it is then placed between a number of thicknesses of clean white blotting-paper and pressed until dry. Unless alcohol is used after the water, the ink will tend to come off on to the blotting-paper. The alcohol also hastens drying

Whenever possible papyrus should be mounted between glass, but if for any special reason it should be necessary to fasten it to paper or card, all adhesives except gum or starch paste must be avoided, otherwise should it be desired to remove it at any time, this might be impossible without damage

Photographic developing dishes make excellent receptacles for use when soaking papyrus in water or other solution.

aper Modern paper of the best quality is made from linen and cotton rags, and other qualities from esparto, wood, straw, and other fibrous materials, but old documents are always of linen or cotton

Paper is not likely to contain salt, but old paper is generally discoloured and frequently

dirty, stained and disfigured, and sometimes very brittle.

Discoloration due to age is largely a process of oxidation brought about by natural means, and it takes place in proportion to the extent to which the paper has been exposed to the air and light, and hence the outsides and edges of old documents, which are the most exposed, become the most discoloured, the discoloration progressively diminishing towards the less exposed parts Other causes for the discoloration of old documents are exposure to dust and dirt, occasional staining by liquids, grease, ink, the excreta of rats, mice and insects and disfigurement by fungus growths, the outsides and edges generally suffering the most Sometimes isolated brown spots caused by iron or other impurities also occur

No attempt should be made to bleach the natural discoloration due to age, as this is not unpleasing, and is an evidence of genuineness in a document and any treatment would only tend to make the paper more tender.

Oil and grease may be removed by soaking the paper in petroleum spirit, which is without any injurious effect upon either the paper or the writing and which quickly dries If soaking is impossible the grease may be

largely removed by means of the same reagent applied to the back of the paper on a tuft of cotton-wool. This will always spread the stain to some extent, but generally in such an attenuated form that it will be scarcely visible.

Writing ink as first used was composed of finely divided carbon suspended in water by means of gum, but later (possibly about the fourth century A D and certainly by the seventh century) an ink made by mixing an iron compound with an infusion of galls was introduced and gradually superseded the older carbon ink for general use, although for special purposes, and in the East, carbon ink is still employed to some extent Carbon ink is generally very permanent, but when once removed from the paper it cannot be restored. Iron ink, on the other hand, is not very permanent and gradually becomes brown and faint or fades entirely, but may be restored temporarily by brushing over with a solution of yellow ammonium sulphide or by exposure to the vapours of the same compound, or more permanently by brushing over with a solution of tannic acid in water or of potassium ferrocyanide rendered slightly acid with hydrochloric acid. The latter gives a blue

colour, which may be turned brown by treatment with dilute ammonia solution. Stains made by carbon ink are not likely to occur, but if present, may be removed by means of warm water and gentle rubbing Ink stains, if made anciently by an iron ink, may be removed by applying to the stained area as small a quantity as possible of a dilute solution of oxalic acid or tartaric acid, allowing it to remain a few seconds, soaking up the excess with clean white blotting-paper, repeating the application of acid if necessary, and finally well washing by applying drops of water several times and each time soaking up the water with blotting-paper. Stains made with a modern blue-black ink, which is an iron ink containing a blue colouring matter, generally an aniline dye, may be removed by applying alternately oxalic acid (or tartaric acid) and a dilute solution of bleaching powder (or of sodium hypochlorite), the excess solution being soaked up with blotting-paper and the places finally well washed with water as already described

Fungus growths on old paper are frequently dead, but if not they may be killed, and so prevented from spreading, by brushing the places attacked with a solution of thymol in

alcohol or in petroleum spirit or by immersing the paper in these solutions.

Photographic developing dishes make excellent receptacles for use when immersing documents in a solution of any sort Should it be necessary for any special reason to soak a document in water, it should be laid on a sheet of glass slightly smaller than the dish, so that in removing it from the water it may be lifted out on the glass without the paper being touched, as wet paper is very tender and tears easily. In the absence of a sheet of glass, the water should be poured off carefully and the document left in the dish to dry, when it may be removed with safety

ient
llum

Parchment and vellum are essentially the same material, and are both made from the skins of animals, the former from the skins of sheep and goats, and the latter, which is of finer quality, from the more delicate skins of calves and kids

Both parchment and vellum swell when wetted, and therefore cannot be cleaned with water, but may be cleaned with petroleum spirit applied on a tuft of cotton-wool

tures

Paint —Paint is of so many different kinds and varies so much, not only in respect to the material on which it is executed but also in the nature of the pigments employed,

that no general methods, either of cleaning or preserving it, are possible. The subject is also so large and to a great extent beyond the scope of the present book that a few aspects of it only will be considered.

Cleaning.—The method of cleaning paint depends upon many factors, including not only the nature of the ground upon which it occurs, but also the nature of the priming, pigments, medium and varnish employed. Paint which has been varnished, or which has been executed in wax, or coated with wax, may be cleaned from dust and dirt by first brushing carefully with a camel-hair or other soft brush, and then sponging with a small damp sponge or damp tuft of cotton-wool or brushing with a soft damp brush.

Unvarnished paint should not be cleaned with water, as this would also generally remove the pigment, but may be cleaned by means of petroleum spirit or alcohol, which are best applied on a tuft of cotton-wool or with a camel-hair or other similar soft brush Petroleum spirit, too, is generally safe to use on varnish, but not on wax, while with alcohol the reverse is the case, and this may be used on wax, but not on varnish

Preservation—As both the material on which the painting is executed and the pig-

ments employed may require preservative treatment, these will be separately considered.

Materials of Ground.—The materials on which painting is done comprise canvas, gesso, paper, papyrus, plaster, stone and wood. Most of these materials will be described in other connections, as also the damage to which they are subject and the methods of preventing damage or the remedy when it is too late for prevention. A little repetition, however, may not be out of place.

Canvas, paper and papyrus, if kept in a damp place, are all liable to be attacked by fungus growths. The first remedy, therefore, is to remove the object to dry surroundings, and then, if possible, to treat it with something that will kill the fungi without injuring the material Many otherwise excellent fungicides are inadmissible on account of their being water solutions, or because they are liable to slow decomposition with the production of bodies that would destroy the material on which it was used, canvas paper and papyrus being very susceptible to the action of even small quantities of acid substances and of chlorine. Thymol, which has been proposed by Dr. Alexander Scott,[1]

[1] *The Cleaning and Restoration of Museum Exhibits*, Dept of Sci and Ind Research, London, 1921.

for destroying fungus growths on prints, is also both safe and satisfactory for paper other than prints, and also for canvas and papyrus The object is enclosed in an air-tight case and exposed to the vapour of thymol, which is a solid body easily volatilized on gently heating, which may be done by means of an electric lamp.

Gesso and plaster, both being injured by moisture, must be kept dry, but gesso on wood should not be dried too much, otherwise the wood shrinks and the gesso breaks off Gesso on wood may be consolidated by impregnating it with melted paraffin wax. This, however, always darkens wood and therefore alters the colour values of any pigments present.

Wood is liable to be attacked by boring beetles, the best remedy for which, in the case of small museum objects which are painted, is fumigation with carbon disulphide, which when pure has no deleterious effect on the pigments.

Pigments.—Many pigments are acted upon injuriously by light, and therefore need to be protected, not only from direct sunlight, but also from too great an exposure to diffused daylight. There are, however, exceptions to this, and in some cases the exclusion of light

is harmful and not beneficial. Thus certain paints are liable to darken in the absence of light, and it is a common experience in Egypt to see paint on woodwork quite white where exposed to light and discoloured and yellowish where protected from light, as for example on walls beneath pictures and on the inner sides of doors standing permanently open against walls

Many pigments too are acted upon injuriously by moisture and particularly when the moisture carries in solution sulphur acids, such as are generated by the burning of coal and coal gas Protection both from moisture and sulphur compounds, however, is not a difficult matter, and consists in proper attention to heating and ventilation, together with the exclusion of gas lighting and gas fires

In cases in which a pigment has faded or changed colour, nothing as a rule can be done to restore it. To this, however, there is one exception, namely, when the pigment is white lead (flake white) which has become discoloured by sulphur compounds. The black sulphide of lead formed may be converted (oxidized) into white sulphate by means of hydrogen peroxide, but this reagent cannot safely be used if pigments other than white lead are present, as some

of the other colours might be injured. The simplest way of applying hydrogen peroxide is in the form of a solution in either water or ether, and preferably the latter, which is painted on the blackened pigment with a camel-hair brush. This same method may be applied to blackened white lead on illuminated manuscripts.

Unvarnished paint on gesso, plaster, stone and wood may be protected and caused to adhere again by spraying with a dilute solution of celluloid or of cellulose acetate.

In connection with paint, the black paint-like coating on many ancient Egyptian wooden funerary objects, already referred to, may again be mentioned This is not a paint, but a kind of varnish, consisting of a natural black resin of a lacquer-like character, such as is found and used in India, China and Japan at the present day. It was applied directly to the wood, and sometimes is not now very adherent Being a resin it is soluble in such reagents as alcohol and acetone, and if sprayed with either of these solvents, should it show signs of flaking off, it softens at the edges and adheres again. The spraying makes the surface very glossy, but in many instances this was the original appearance.

ery By pottery is meant vessels and ware made from clay and then hardened by being baked ; it may be either glazed or unglazed ; Egyptian faience and porcelain are not included.

Pottery is very resistant to the ordinary processes of decay, and its weakness lies in its fragility and often in its porosity, the latter being characteristic of unglazed pottery.

The fragility of pottery allows it to be easily broken and the porosity permits it to become impregnated with various substances, fatty matter, for instance, in the case of jars containing fat, or salts from salty ground, which latter may ultimately cause disintegration if the salts should have an opportunity of crystallizing

Pottery is sometimes disfigured by incrustations of carbonate or sulphate of lime, or both, derived from wet ground containing these substances

As a rule the first step towards cleaning pottery is to wash it well with water and a soft brush. If salt is present the object must be soaked in repeated changes of pure water until all the salt is dissolved out. This will take some days and possibly several weeks.

Fatty matter may be removed by soaking the object in petroleum spirit, but it must be dry before treatment.

No attempt should be made to remove either carbonate or sulphate of lime by scraping, as this would not only be useless, but might also scratch or disfigure the object. Carbonate of lime may be removed by brushing it repeatedly with a dilute solution of hydrochloric acid (2 to 5 per cent.). Sulphate of lime generally falls off during soaking in water to dissolve out salt or softens sufficiently to be readily detached, but may be removed by treatment with hydrochloric acid in the same way as for carbonate. After acid, the object must be washed in repeated changes of water until no trace of acid remains Baking will cause sulphate of lime to crumble to powder and fall off, but frequently the object is too large for baking to be conveniently applied.

The exceptions to the above-mentioned methods of treatment are objects that have been painted after having been fired and also fragments of pottery bearing written inscriptions Although these may generally be soaked in water without damage, if the soaking is not too prolonged, this must not be taken for granted, and they should be well watched for some time after being placed in the water. Great care is necessary in handling painted pottery, or pottery

bearing ink inscriptions, while wet, as both paint and ink then easily rub off.

It is well known that an ink inscription on pottery (also on stone or wood) is more visible when wet, and therefore inscriptions are often wetted in order that they may be deciphered. This is most unwise, and is very liable to destroy the inscription. A perfectly safe way of bringing up ink inscriptions is to spray them with petroleum spirit or alcohol. The effect, as with water, is only temporary, but the treatment may be repeated as often as necessary without danger.

Acid should never be used on painted pottery until it has been proved by an experiment on one small portion that it will not injure the colour.

Pottery may be repaired with celluloid cement if the objects are small, but in the case of large objects, glue or plaster of Paris suitably tinted should be used Missing portions may be replaced by tinted plaster, which is afterwards treated with celluloid, cellulose acetate, paraffin wax or stearine as already described [1]

tone The stone used in antiquity was of many different kinds, the principal varieties being alabaster (calcite), limestone, marble, sand-

[1] Pp 19–22.

stone and igneous rocks, such as basalt, diorite, dolerite and granite. In many instances stone objects have been exposed to atmospheric influences during thousands of years and a certain amount of disintegration has been produced, chiefly by variations of temperature, the mechanical action of wind-borne particles of sand and the solvent action of water, generally rain containing carbon dioxide in solution. The damage cannot be remedied, but as soon as the stone is removed from the sphere of action of the agents mentioned disintegration ceases. In addition, however, to the causes of damage enumerated, there is one other factor, which is the most potent of all, and which is largely responsible for the disintegration and destruction of limestone and sandstone in dry countries such as Egpyt, chiefly because these two stones are soft and porous. This destructive agent is salt, which consists largely of chloride of sodium (common salt), but sometimes is a mixture of common salt and sulphate of soda, with occasionally small proportions of other salts, such as carbonate of soda, nitrate of soda and nitrate of potash The action of salt on stone is not analagous to its action on metals, and as a rule is not chemical, but

entirely physical, and is caused by the salt crystallizing underneath the surface layers of the stone, which are forced off by the irresistible expansion consequent on the crystallization. For such action to take place four conditions are necessary, namely, firstly, the presence of water-soluble salts, secondly, the presence of water to dissolve the salts, thirdly, porous stone, and fourthly, opportunity for the salts to be brought to the surface of the stone by capillary attraction and there to crystallize out, owing to the evaporation of the water holding them in solution

With the exception of limestone, very few stones naturally contain more than a trace of soluble salts, but limestone may contain several per cent., and the author has found as much as 4 6 per cent of water-soluble salts in a specimen of limestone taken direct from the quarry As a rule, however, when stone contains much salt, this has been derived from salty ground in which the stone has lain.

Excepting limestone and sandstone, few stones are very porous, and therefore generally it is only these two kinds of stone that contain salt. When a stone is quite dry, salt is harmless, but it is almost impossible to

keep a salty stone dry, since salt attracts and absorbs water even from a damp atmosphere.

Since the salts causing mischief are soluble in water the obvious way of removing them is to soak the stone in water until it is free from salt. In many cases, however, this cannot be done, because the object is too large and in other cases it is only possible to do it without damage if certain precautions have been taken, on account of the stone having a plaster surface or bearing a painted inscription, or both. In those cases in which soaking is possible and permissible, the object should be entirely immersed in water contained in a stone or cement basin or in a wooden box lined with lead or zinc, but not in iron or tinned iron The object should be raised above the bottom of the vessel, preferably on brick or stone supports, but not on metal, as such metals as iron or copper would discolour the stone The water must be changed frequently until on testing it is found to be free from more than a trace of salt. This will take many weeks and often months. The stone when removed from the water is allowed to dry slowly in a warm place. In this connection it should not be forgotten that water has a slight sol-

vent action on limestone, and with prolonged soaking the sharp outlines of carvings and inscriptions may suffer. The growth of algæ, which tend to develop, especially in warm weather, may be prevented by frequent changing of the water, by covering the vessel so as to exclude the light, and by dissolving in the water a very small proportion of copper sulphate.

Sometimes patches of crystals of sulphate of lime occur on stone objects that have been buried in damp ground Any such crystals will either fall off during soaking in water or will so soften that they may readily be detached Acids should not be used, as they act vigorously upon limestone and dissolve it and, even in the case of sandstone, the material cementing together the grains of sand will probably contain carbonate of lime and this would be attacked by acid

Stone objects, which bear painted inscriptions, must on no account be wetted until the painted surface has been protected from the action of water, or the paint will probably be destroyed. The necessary protection may be given by spraying or otherwise treating the surface of the stone with some material that is insoluble in, and unacted upon by, water. Such substances are celluloid,

cellulose acetate, dammar resin, mastic resin and shellac, a description of which, with the manner of making and using, has already been given.[1] Preservatives of unknown composition should never be employed, and all substances such as silicate of soda (water glass), silicate of potash, silico-fluorides (fluosilicates, fluates) and baryta should be avoided, not only because they can only be used in aqueous solution, but also because they generally form a thin skin on the surface of the stone which eventually scales off, while as a secondary effect they often cause an efflorescence of salt which increases any disintegration taking place Linseed oil, which is sometimes advocated, should not be used, as it darkens the colour of the stone.

Occasionally limestone naturally contains veinlets of common salt, or is so largely impregnated with salt that it is barely holding together In such cases washing with water would be fatal and the only remedy is to treat the stone with a preservative without attempting to remove the salt When the disintegration is less pronounced the object may be wrapped in gauze or bound round with fine string before being soaked.

Sometimes objects bearing painted inscrip-

[1] Pp. 30–32.

tions have a layer of plaster under the paint or have had irregularities in the stone smoothed over with plaster. Such objects cannot be wetted without the plaster coming off, and if salty they must be treated with one of the preservative solutions mentioned without any attempt being made to remove the salt.

Black spots, which occasionally disfigure limestone, but more often sandstone, are generally due to oxide of manganese or mixed oxides of iron and manganese, natural to the stone, and cannot be remedied

Sometimes stone objects are wantonly disfigured, and in such cases the method of treatment naturally depends upon the nature of the material used In one instance in Egypt the walls of a number of chambers in the Temple of Rameses II at Abydos were smeared with a black material which proved to be a carbon writing ink The greater part of this was removed by sponging with water, but in places a 5 per cent solution of carbonate of soda was used The report states that on the whole the treatment was successful, but that there was a slight *dégradation* of the colour of the paint[1]

[1] *Annales du Service des Antiquités de l'Egypte* Tome xii Le Caire, 1912

The carbonate of soda, however, was unnecessary, and might have caused damage.

In this connection a brief record of what has actually been done in the way of preservative treatment of painted surfaces on stone and plaster may be useful, and the following have been traced:

1. The paintings on the walls of tomb No. 22 (Wah) at Thebes which were rapidly disappearing owing to the powdery state of the colours were sprayed three times, first with a weak and then with a strong solution of albumen. It is stated that this has effectually fixed the colours, that no stain or darkening has been caused, and that, owing to the colours being painted directly on the stone, there is no danger that the albumen will be attacked by white ants.[1]

2. The colours on the plaster of the Tel-el-Amarna pavement were fixed by means of tapioca water, applied just thick enough to soak entirely in without leaving any glair on the surface.[2]

3 The limestone blocks forming the tomb

[1] *Annales du Service des Antiquités de l'Egypte.* Tome xiv. Le Caire, 1914.

[2] *Tel-el-Amarna* W. H. Flinders Petrie, London, 1894.

of Perneb, which was removed from Egypt and re-erected in the Metropolitan Museum of Art, New York, were being damaged by an efflorescence of salt Immersion in water was impossible owing to the presence of plaster, which had been freely used to fill out and conceal imperfections in the stone, and the painted surfaces of the blocks were therefore treated " in such a way as to bottle up the salts. . . ." [1] The preparation used is a proprietary one, but it is believed that it contains Chinese wood oil, resin and fatty acids

In the author's opinion a solution of celluloid is preferable to any of the three materials mentioned and also more efficacious. Fatty acids should certainly be avoided, as they cannot fail to have some, though possibly only slight, solvent action on limestone.

As a rule, stone objects are best repaired with plaster of Paris suitably tinted, unless the object is small, when celluloid cement should be used.

tile rics

Textile fabrics vary very much in their state of preservation, being at times in excellent condition and at other times badly decayed and falling to powder.

[1] *The Tomb of Perneb*, New York, 1916.

The reason for the disintegration of textile fabrics is not fully understood, but the factors which appear to be of importance in this connection are air, heat and humidity, and it seems probable that the changes are partly chemical and partly biological, the chemical action being in the nature of oxidation and the biological effects being brought about by bacteria and fungi (moulds)

When textile fabrics are in a good state of preservation, but contain salt, as may happen in wrappings or garments on bodies that have been treated either with natron or salt, the salt may be removed by soaking in repeated changes of pure water. Soaking in water, however, would be fatal to fabrics in a tender condition.

Merely ironing a textile fabric, with or without slight damping, will often considerably improve and strengthen it.

The best way to strengthen fabrics which are in a tender condition, is to spray them with a solution of celluloid or of cellulose acetate. On no account should paraffin wax be used, as it masks all pattern and colour and is a great disfigurement.

To prevent the attacks of insects and moulds, textile fabrics should be kept in well-fitting cases in a dry atmosphere and

should be sprayed with a solution of mercuric chloride in alcohol, which must be used with care, as it is very poisonous, or with a solution of naphthalene in carbon tetrachloride If actually attacked, the best remedy is fumigation with carbon disulphide, which may be carried out by exposing this reagent in open dishes in the cases and allowing it to evaporate. Solid naphthalene in the case confers a limited degree of protection against certain kinds of insects.

d Wood is subject to many ills, including the attacks of insects and fungi, the action of water-soluble salts and staining by oil. These will now be considered.

Insects —The principal insects that destroy dead wood (excluding marine woodboring molluscs and crustaceans) are white ants (termites) and several kinds of boring beetle

The white ant is sometimes found infecting ancient tombs, as in certain parts of Thebes and at Tel-el-Amarna, and in such cases there is no remedy, since the mischief will already have been done before the tomb or other excavation is opened, and wooden objects, unless they are made of a few certain kinds of wood which seem to be immune, will be entirely destroyed when found Museums, too, are occasionally invaded by

white ants. When there is any danger of this the enemy may be kept out by the following mentioned precautions, namely, (*a*) clear spaces covered with sand, gravel, stone, brick or asphalt surrounding the building, (*b*) all woodwork to be insulated from the ground by at least a foot of stone, burned brick or concrete; (*c*) floors to be of stone, cement or tiles and not of wood; (*d*) show-cases and wooden objects resting on the floor to be protected by metal sheeting underneath. Other remedies, such as tar, creosote and paint also protect wood against white ants, but cannot be applied to antique objects.

Boring beetles may be kept out of wooden objects by well-fitting show-cases If an object is already infected, the best remedy for ordinary application to small objects is fumigation with carbon disulphide This may be done in the show-case itself by leaving some of the liquid exposed for a week or two so that it will evaporate and saturate the air and also the contents of the case. Carbon disulphide being volatile and very inflammable, special precautions must be taken against fire. Other methods that may be employed are spraying with a solution of mercuric chloride in alcohol, with

benzol or with naphthalene dissolved in carbon tetrachloride.

Fungi.—The well-known decay of wood called "Dry Rot" is caused by several kinds of fungi. The term, however, is a misnomer, and the decay is not due to the wood being dry, since moisture must be present before the fungi will grow, but to the dry powdery appearance of the wood when badly attacked. The conditions that are most favourable to the production of dry rot are a warm, moist and stagnant atmosphere. The preventives are good ventilation and spraying with a fungicide, such as a solution of mercuric chloride in alcohol Fungicides dissolved in water are not recommended, as all wetting of wood should be avoided whenever possible

Salts—It is not very usual to find salts in wooden objects, but they occur occasionally, and are always derived from the ground in which the objects have been buried When salts are present it is chiefly in the form of common salt, though Scott mentions [1] a case in which wooden objects were impregnated with ammonium compounds derived

[1] *The Cleaning and Restoration of Museum Exhibits*, Dept of Sci and Ind Research, London, 1923

from guano. Although when dealing with wooden objects the use of water should be avoided if possible, there are instances, such as the presence of salt, where the only remedy is to soak the object in water or in a water solution · for example, to remove the ammonium salts mentioned Scott used dilute acetic acid followed by washing in water. After having been wetted the objects must be dried carefully and above all, slowly. This is essential. Soaking in alcohol after the water helps drying If objects have been found in water or in a damp situation it is difficult to dry them in the ordinary way without warping, and in such cases the best method is to place them on a grating in a vessel containing paraffin oil (kerosene) and allow them to remain until all the water has been replaced by oil. They are then immersed in petroleum spirit until this in turn displaces the paraffin oil. The objects should then be well drained and dried and impregnated with hot melted paraffin wax Paraffin wax, the use of which is due to Flinders Petrie, is one of the most valuable remedies for the treatment of wooden objects in a bad state of preservation. If possible, the object should be well warmed before applying the wax, if the object is warm and

the wax very hot the wax all soaks in without leaving any excess on the surface to cause disfigurement. However, should any surplus be left, this may be removed by heat or by means of a soft cloth or a soft brush soaked in petroleum spirit. Wax has one great drawback, namely, that it darkens wood, and if the wood is painted, but not varnished, this darkening shows through and alters the colour values of the pigments, white especially being much darkened. On a painted but varnished surface wax has no darkening effect.

Oil.—Oil or grease may be removed by soaking the object in benzol or in petroleum spirit, or, if this is not possible, the stains should be treated with either of these solvents applied with a rag.

CHAPTER IV

SIMPLE PHYSICAL AND CHEMICAL TESTS

Physical Tests

Detailed physical examination or chemical testing are matters for the specialist, but the knowledge of how to carry out a few simple tests will be advantageous alike to the archæologist, the curator and the collector. A few tests therefore will be described The physical tests should be done before the chemical ones, as generally the amount of material available is limited The materials mentioned are those likely to occur in connection with antique objects.

The physical tests are as follows

1. Examination with a lens.
2. Hardness
3. Fracture
4. Specific Gravity.

These will now be considered in detail

ination a Lens From the examination of a material with a lens much may be learned, and details of colour, structure and composition not visible

to the naked eye may be seen Specimens of known and likely materials should be examined alongside the doubtful material. A good hand lens or a watchmaker's eye-glass is recommended.

ess Hardness is a most useful test for the examination of mineral substances. The hardness may be determined in several different ways: firstly, by scratching the material with the thumb-nail, secondly, by scratching it with the point of a penknife, thirdly, by rubbing the material on a small, fine, clean, hard file and noting the extent to which it is affected, and fourthly, by scratching the material with various minerals of known hardness.

The hardness of a mineral is expressed by a number. The following tabular statement shows the hardness of the principal materials likely to occur. The thumb-nail will scratch minerals of a hardness not exceeding 2 5, and a penknife will scratch minerals up to a hardness of about 5 5, thus gypsum may be easily scratched with the nail, whereas alabaster (calcite) requires a knife to scratch it and quartz cannot be scratched even with a knife, which means that it is harder than steel The minerals with a hardness of 6 will just scratch window

glass, while those with a hardness of 7 or upwards scratch glass easily. When a mineral neither scratches nor is scratched by a particular substance the hardness of the two is the same. After making a scratch the powder should be wiped off and the surface examined with a lens in order to make sure that the powder does not come from the scratching agent, which may happen when the two substances are of nearly the same hardness.

TABLE OF HARDNESS

Number	*Material*
1	Steatite.
2	Gypsum.
2·5	Amber, galena.
3	Alabaster (calcite)
3 5	Malachite.
4	Serpentine
5 5	Glass, lapis lazuli, obsidian.
6	Feldspar, hæmatite, turquoise.
7	Agate, amethyst, carnelian, chalcedony, flint, jasper, quartz, rock crystal.
7 5	Aquamarine, beryl, emerald
8	Topaz
9	Sapphire.
10	Diamond.

Fracture The nature of the fracture produced when minerals and other materials are broken is very characteristic. Examples of different kinds of fracture are as follows

1. *Conchoidal.*—When the broken surface

is curved, either convex or concave. Examples: Amber, flint, glass, obsidian, quartz.

2 *Even.*—When the surface is flat or nearly so. Example. Chert.

3. *Earthy*—Example: Chalk.

ific vity The specific gravity of a substance is the ratio of its weight to that of an equal volume of water. The small variations due to differences of temperature may be neglected in determinations such as those under consideration.

The ordinary laboratory methods of determining the specific gravity of a solid body by weighing first in air and then in water, or by ascertaining the loss of weight in water from the weight of water displaced, cannot be employed in the absence of the necessary apparatus, and as this is not usually possessed by archæologists or curators the methods become impracticable. Two other methods, however, are very simple, and require only such apparatus as may readily be obtained The results, although only approximate, are sufficiently accurate for the purpose required The methods are as follows

1. If the object is of a regular shape that may be easily measured, such as an oblong or square, measure three dimensions (height,

width and depth) and calculate the cubic contents, then weigh it and calculate the weight per cubic centimetre or per cubic inch. Since 1 cubic centimetre of water weighs 1 gram (15·4 grains) and 1 cubic inch of water weighs 16 4 grams (252·6 grains), the gravity may readily be calculated. This does not allow for any air present, and therefore with porous objects represents the apparent and not the real specific gravity.

2. By measuring the displaced water. Take a small glass cylinder graduated in cubic centimetres, partly fill it with water and note the volume, then carefully put the object into the water and again note the level of the water. The difference between the two readings is the volume of water in cubic centimetres displaced by the object. But since 1 cubic centimetre of water weighs 1 gram, the volume in cubic centimetres also represents the weight in grams The specific gravity of the object is its weight in grams divided by the weight of water displaced, also in grams If the object is a large one, the experiment may be done in a beaker, the two water levels being marked by strips of gummed paper and the water displaced poured into a graduated cylinder for measurement.

The specific gravities of a few materials are given in the following table

Specific Gravity	*Material*
1 1	Amber.
2·3	Gypsum
2·4 to 2 5	Lapis lazuli
2·5 to 2 6	Obsidian, serpentine.
2·5 to 3	Glass.
2 6	Agate, amethyst, carnelian, chalcedony, jasper, quartz, rock crystal.
2·6 to 2·8	Feldspar, turquoise.
2·7	Alabaster (calcite), beryl, emerald.
2 7 to 2·8	Steatite
2 9	Aragonite
3·5	Topaz.
3 5 to 4	Malachite
5 0	Hæmatite
7 5	Galena

Chemical Tests

The apparatus required for the chemical tests consists of a few small test-tubes, a few watch glasses, some thin iron wire and blue and red litmus paper The chemical reagents required, together with the strengths of the solutions to be used, will be found described later

The tests are as follows

1. Solubility
2. Behaviour on heating
3 Reaction with acid.
4 Testing of solutions formed when the material is soluble in water or acid
5. Flame coloration.

These will now be described. Before undertaking any chemical tests it should be seen that all reagents are pure and all apparatus thoroughly clean.

bility For solubility a small quantity of the material is powdered finely and tested to see whether it is soluble, first, in water (distilled if possible), secondly, in alcohol, and thirdly, in petroleum spirit This may be done on a watch glass or in a small test-tube.

Soluble in Water.—Carbonate of soda, nitrate of soda, sulphate of soda, nitrate of potash (saltpetre), salt (common salt, rock salt). Glue and gum are first softened by water and then dissolved. Clay disintegrates in water and feels soapy

Soluble in Alcohol—Resin, resin varnish, wood pitch

Soluble in Petroleum Spirit.—Bitumen, fat, grease, mineral pitch, oils.

aviour eating To apply the heating test place a small piece of the material on the point of a penknife and heat in the flame of a gas-jet, spirit-lamp or candle Note (*a*) whether the material melts, (*b*) whether the material burns, and if so whether it burns freely, (*c*) the smell produced, and (*d*) the nature of the residue, if any. If the material melts before it burns it is possibly fat, resin or

wax (beeswax) Smear it while melted on a piece of white paper. A greasy stain indicates either fat or wax. If the material burns it is most probably organic, although it should not be forgotten that some inorganic substances, sulphur for example, also burn. Other inorganic materials, such as ammonium chloride, disappear when heated by volatilization and not by burning. The smell of the burning material is often very characteristic, and bitumen, fats, mineral pitch, oils, resin, sulphur and nitrogenous matters (hair, horn, mummy flesh) may all be identified by the smell.

on
cid

To test the reaction with acid, take a few small fragments or scrapings if the object is one that may be cut or scraped, powder them finely, and place a little of the powder in a small test-tube and pour on it a little dilute hydrochloric acid and watch the result. If the object may not be cut or scraped, place on it in an inconspicuous place (by means of a small pipette or a fine glass rod) a small drop of dilute hydrochloric acid and watch the result with a lens.

The following named are soluble with effervescence Alabaster (calcite), carbonate of lime, chalk, limestone, malachite (forming a green solution), marble, whiting

The following named is soluble without effervescence · Sulphate of lime (gypsum)

ng of tions

Water Solution—The solution formed by dissolving any material in water should be tested as follows:

1. For alkalinity and acidity, which may be done by means of litmus paper. If the solution is alkaline, red litmus turns blue, whereas if the solution is acid, blue litmus becomes red.

Alkalinity in connection with antique objects generally signifies natron (which contains carbonate of soda). Acidity is unusual, and not likely to occur in a water solution.

2 For the presence of chloride, which will generally indicate common salt or natron (which contains salt)

Chloride is tested for by means of nitrate of silver To a little of the solution contained in a test-tube or in a watch glass add a few drops of a solution of nitrate of silver A milkiness indicates a trace of chloride and a curdy precipitate means a larger amount This should be confirmed by adding a few drops of dilute nitric acid, which should not produce any change, that is to say, the milkiness or precipitate should not disappear. Ordinary pure water contains a trace of chloride, and well water often contains a considerable amount.

3. For the presence of sulphate, which will generally indicate sulphate of soda, but may mean sulphate of magnesia.

Sulphate is tested for by means of chloride of barium. To a little of the water solution contained in a small test-tube or in a watch glass add a few drops of a solution of chloride of barium. A slight cloudiness appearing after a time indicates a trace of sulphate, a heavy white precipitate indicating a larger amount This should be confirmed by adding a few drops of dilute hydrochloric acid, which should not dissolve the precipitate. Care should be taken not to make the solution too acid, otherwise the hydrochloric acid will produce a precipitate, which, however, disappears on diluting with water.

Acid Solution —This should be tested for sulphate in the same manner as described for the water solution. A precipitate with chloride of barium indicates sulphate, which, in the absence of sulphate in the water solution, will generally mean sulphate of lime (gypsum). Chloride cannot be tested for in the acid solution, as the acid itself would give the reaction.

For the flame coloration test scrape off a little of the material, place it on a watch glass and add a few drops of strong hydrochloric acid Dip the end of a thin piece

of clean iron wire in the solution and hold it in the outer zone of the flame, about one-third of the way up, and note the colour produced. This may be as follows.

Yellow.—This is the most common, and indicates sodium compounds, but as these are so widely distributed, occurring even in the dust in the air, a yellow coloration, unless very vivid, may be disregarded. Without other tests it is impossible to say what particular sodium compound is present.

Red.—This indicates calcium compounds, such as alabaster, gypsum, limestone, and whiting.

Blue and Green.—These indicate copper compounds.

ary of ults of emical Tests

Beeswax.—Almost insoluble in alcohol, slightly soluble in petroleum spirit, soluble in chloroform and in carbon disulphide, melts when heated, burns with a smoky flame and gives a characteristic smell

Bitumen (Mineral Pitch)—Insoluble or only slightly soluble in alcohol, soluble in petroleum spirit, giving a brown solution, burns with a smoky flame, giving a characteristic smell.

Carbonate of Lime.—This occurs as alabaster (calcite), chalk, limestone, marble, whiting It is soluble with vigorous effervescence in hydrochloric acid, and the solu-

tion imparts a red colour to the flame.

Carbonate of Soda.—Soluble in water, soluble in hydrochloric acid with strong effervescence, imparts a very vivid yellow colour to the flame, water solution alkaline to litmus

Glue—Softened and finally dissolved by water, the solution frothing readily on agitation, insoluble in alcohol, gives a disagreeable nitrogenous smell on burning.

Gum—Soluble in water, insoluble in alcohol, does not melt but chars on heating, no nitrogenous smell on burning

Lapis lazuli—This is a double silicate of aluminium and sodium associated with sulphide of sodium and contains patches of carbonate of lime, and often iron pyrites. It is soluble in strong hydrochloric acid, sulphuretted hydrogen being evolved and the white patches giving effervescence.

Malachite—This is hydrated carbonate of copper. It is soluble in hydrochloric acid with effervescence, giving a green solution of chloride of copper which imparts a blue coloration to the flame Copper compounds, other than chloride, colour the flame green Bright steel, such as the blade of a knife, introduced into the hydrochloric acid solution becomes covered with a thin coating of metallic copper.

Natron.—This is a compound of carbonate and bicarbonate of soda, which occurs naturally in Egypt and was used by the ancient Egyptians in embalming; it always contains an admixture of common salt and sulphate of soda, and therefore will give the reactions for these substances. It imparts a very vivid yellow colour to the flame and is alkaline to litmus.

Resin.—Soluble in strong alcohol, insoluble in water, insoluble or only slightly soluble in petroleum spirit, melts with heat, burns with a smoky flame, giving a characteristic smell like burning varnish.

Salt (*Chloride of Sodium*).—Soluble in water, the solution giving a white precipitate with nitrate of silver, which is insoluble in nitric acid, neutral to litmus, gives a very vivid yellow flame coloration.

Sulphate of Lime (*Gypsum*).—Soluble in hydrochloric acid without effervescence, though not very readily unless heated, the solution imparts a red colour to the flame

Sulphate of Soda.—Soluble in water, the solution giving a white precipitate with chloride of barium, which is insoluble in hydrochloric acid, neutral to litmus, and gives a very vivid yellow colour to the flame.

Reagents and Solutions Required

Only the best quality materials should be employed. Using makeshift or inferior materials (and tools) when good quality ones are readily obtainable is false economy of the worst kind, and cannot fail to affect adversely the quality of the work.

The following list contains the description of all the most necessary reagents and solutions required ·

Acetone, redistilled	For dissolving celluloid and cellulose acetate
Acetic acid, glacial	10 per cent. solution in water for cleaning bronze.
Acid formic, about 90 per cent.	From 5 to 25 per cent solution in water for cleaning silver.
Acid hydrochloric, pure	(*a*) 1 to 5 per cent. solution in water for dissolving carbonates. (*b*) 10 per cent solution in water for testing
Acid nitric, pure .	10 per cent solution in water for testing.

Acid oxalic, pure .	5 per cent. solution in water for taking out ink stains.
Acid tartaric, pure.	5 per cent. solution in water for taking out ink stains.
Alcohol, rectified spirit or good quality methylated spirit at least 90 per cent. strength	For cleaning and dissolving
Ammonia solution, pure, specific gravity, 880	For cleaning. Generally used in 10 per cent. solution
Ammonium chloride, battery crystals.	For cleaning bronze.
Ammonium sulphide solution (sulph-hydrate)	For developing iron ink.
Ammonium sulphite	For cleaning silver.
Amyl acetate, pure	For dissolving celluloid.
Barium chloride, pure	10 per cent. solution in water for testing.
Benzol, pure . .	For cleaning. The more correct name is benzene, but this is liable to be mistaken for benzine
Benzine, good quality	Aviation spirit, petroleum spirit, petrol. For cleaning.

leaching powder .	Must be fresh. For taking out ink stains.
alcium chloride, pure, granular	As a drying agent in museum cases.
anada balsam, best quality	For impregnating enamels.
arbon disulphide, pure	As an insecticide.
arbon tetrachloride, pure	For dissolving naphthalene.
austic soda, pure, sticks	10 per cent. solution in water for cleaning bronze and iron.
elluloid, cuttings .	For varnish, impregnation and cement.
ellulose acetate, soluble in acetone	For varnish, impregnation and cement
opper sulphate, crystals	For cleaning silver.
opper sulphite (cuprous)	For cleaning silver.
ammar resin .	For varnish.
erosene, water-white	Paraffin oil
astic resin . .	For varnish.
ercuric chloride, powder	Corrosive sublimate Used in 2 per cent. solution in alcohol as an insecticide
aphthalene, flake or marbles	As an insecticide.

Paraffin wax, melting-point about 60° C. (140° F.)	For impregnation
Paraffin oil, water-white	Kerosene.
Petroleum spirit, good quality	Benzine, petrol, aviation spirit. For cleaning.
Potassium cyanide, about 90 per cent.	5 per cent. solution in water for cleaning gold and silver
Rochelle salt, powder	Sodium potassium tartrate. 15 per cent. solution in water for cleaning bronze.
Shellac, bleached .	For varnish.
Sodium sulphide, crystals	Used in dilute solution in water for darkening bronze.
Sodium sulphite, anhydrous	For cleaning silver
Thymol	As a fungicide
Tin chloride (stannous), pure	For cleaning bronze
Water	(*a*) Distilled for testing. (*b*) Ordinary pure for washing.

BIBLIOGRAPHY

ARMER, Sir SYDNEY F "Experiments on the Fading of Museum Specimens." *The Museums Journal*, Vol 21. London, 1922

ORNS, A H *Metal Colouring and Bronzing* London, 1920

TRIE, Sir FLINDERS. *Methods and Aims in Archæology.* London, 1904

ATHGEN, Dr F *The Preservation of Antiquities* Translated by G A and H A. Auden. Cambridge, 1905

OUSONPOULOS, O A "On the Cleaning and Preservation of Antiquities" *The Museums Journal*, Vol 11 London, 1911–12

OSENBERG, G A *Antiquités en Fer et en Bronze, leur Transformation . et leur Conservation* Copenhagen, 1917

USSELL, W J, and ABNEY, W DE W "Action of Light on Water-Colours" *Blue Book* London, 1888

OTT, Dr ALEXANDER *The Cleaning and Restoration of Museum Exhibits* First Report, London, 1921 ; Second Report, London, 1923

1265

INDEX